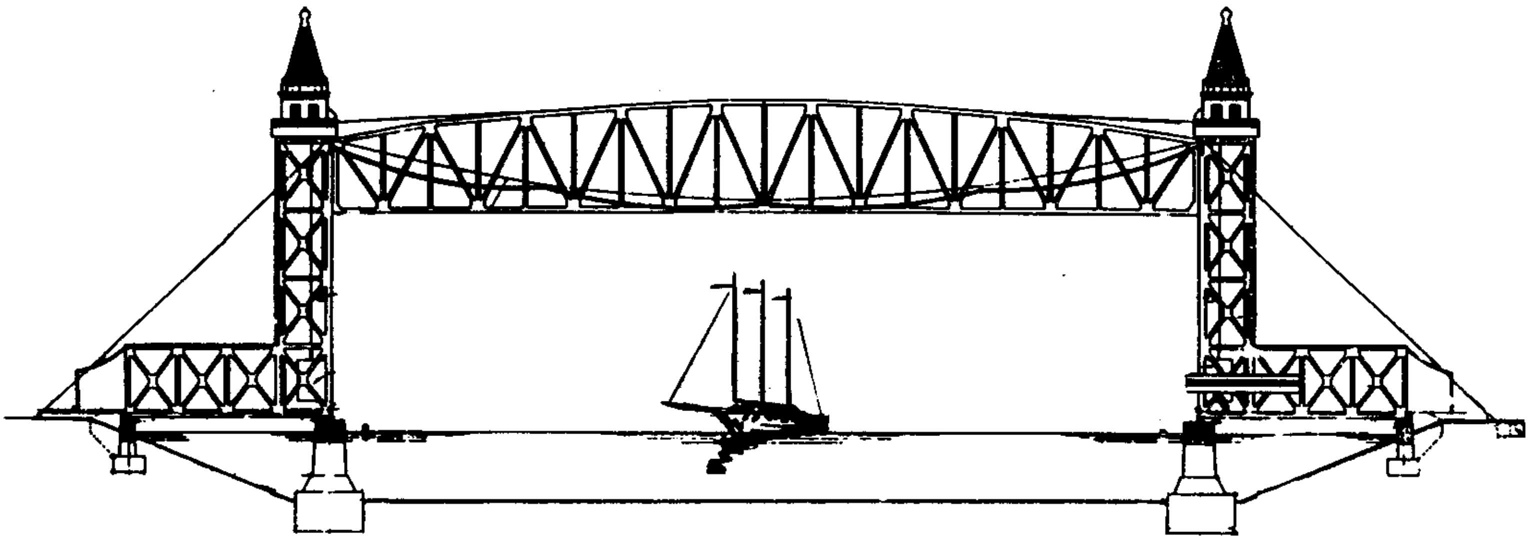
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS



BUZZARDS BAY RAILROAD LIFT BRIDGE OVER CAPE COD CANAL

VOLUME I

INSPECTION AND CONDITION REPORT

OCTOBER, 1984

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E. W. ROHRBAUGH

October 12, 1984

Mr. Richard D. Reardon, Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

RE: CONTRACT NO. DACW33-84-C-0022
Inspection and Condition Report
Vertical Lift Railroad Bridge
Cape Cod Canal
Buzzards Bay, Massachusetts

Dear Mr. Reardon:

In accordance with the referenced contract, we submit, herewith, our report on the inspection, evaluation and condition of the Vertical Lift Railroad Bridge over the Cape Cod Canal at Buzzards Bay, Massachusetts.

Our inspection and evaluation of the structure reveals that the two items that should be of most concern to the Corps are the condition of the counterweight cables and the counterweight sheave roller bearings. The condition of these two items, if not corrected as soon as possible, may further deteriorate to a point where the operation of the lift span will be jeopardized, and adversely affect both rail and canal traffic. We recommend that the condition of these items be given your immediate attention.

We express our appreciation for the excellent assistance and cooperation your staff, in both the Waltham and Cape Cod Canal offices, gave to us during the course of our activities. We trust that the contents of the final report meet with your apppoval. If however, there are questions, do not hesitate to contact us.

Very truly yours,

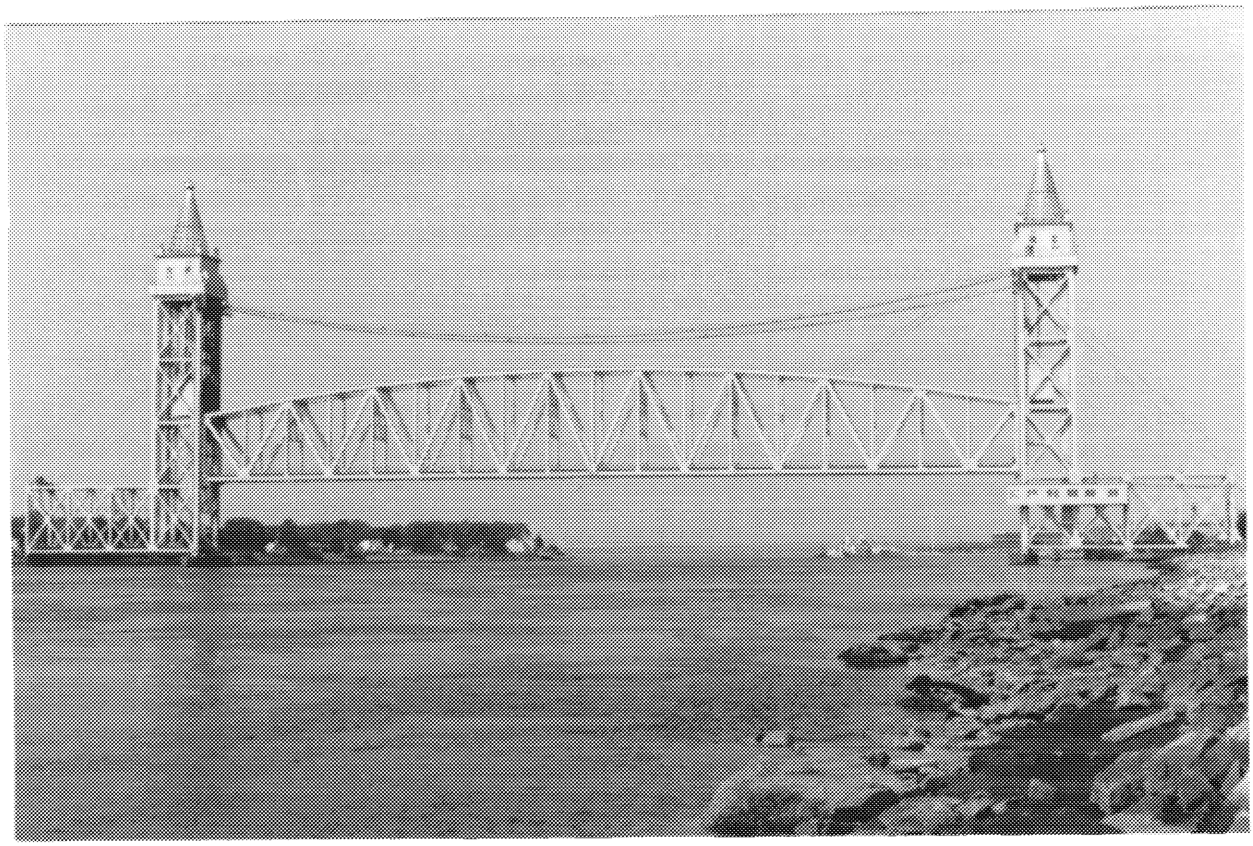
Joseph J. Scherrer

JOSEPH J. SCHERRER,
Partner

JJS:BPS:dmg

encl/as

NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS



BUZZARDS BAY RAILROAD LIFT BRIDGE OVER CAPE COD CANAL

VOLUME I

INSPECTION AND CONDITION REPORT

MODJESKI AND MASTERS
CONSULTING ENGINEERS

BUZZARDS BAY RAILROAD LIFT BRIDGE

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VOLUME I

IN-DEPTH INSPECTION AND CONDITION REPORT
VERTICAL LIFT RAILROAD BRIDGE
CAPE COD CANAL
BUZZARDS BAY, MASSACHUSETTS

I. PROJECT AUTHORITY

U. S. Army Corps of Engineers' Engineering Regulation No. 1110-2-100, dated 28 February 1983, entitled "Engineering and Design, Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures", prescribes the procedures to be followed in periodically inspecting and evaluating those U. S. Army Corps of Engineers civil works structures, whose failure or partial failure would endanger the lives of the public or cause substantial property damage and impair the operational capability and/or serviceability of the structures.

In accordance with the authority derived from ER 1110-2-100, the New England Division, U. S. Army Corps of Engineers entered into Contract No. DACW33-84-C-0022, dated 17 April 1984 with Modjeski and Masters, Consulting Engineers, for a detailed inspection, evaluation and condition report for the Buzzards Bay Vertical Lift Railroad Bridge over the Cape Cod Canal at Buzzards Bay, Massachusetts.

II. PROJECT DESCRIPTION

The Buzzards Bay Railroad Bridge over the Cape Cod Canal is a single-track, open deck steel structure (see Figure 1, location map and Figure 2, a general plan and elevation of the bridge).

The bridge was constructed for, and under the supervision of the, U. S. Army Corps of Engineers. Construction commenced on December 12, 1933, and the bridge was put into operation on December 27, 1935. The bridge is 806 feet long from abutment-to-abutment, and consists of a 544 foot long lift span and two 128 foot long tower spans. The abutments and the piers were constructed within steel sheet piling cofferdams and are supported on oak bearing piles. The abutments and the piers are faced with granite above and below the waterline.

The lift span is power-driven, and it is actuated by four 150 horsepower, 440 volt, 3-phase, 60 cycle electric motors. Auxiliary power can be provided by a 500,000 watt diesel generator.

The bridge has served the New York, New Haven and Hartford Railroad Company; the New York Central Railroad, the Penn Central Railroad; and the Consolidated Railway Corporation. The approach tracks are currently owned by the Commonwealth of Massachusetts. The bridge currently serves the Bay Colony Railroad Corporation of Lexington, Massachusetts, and the Cape Cod and Hyannis Railroad, Inc. of Hyannis, Massachusetts. The Bay Colony Railroad provides freight train services to the Cape several times a week. The Cape Cod and Hyannis Railroad, Inc. operates four daily passenger trains to Buzzards Bay from the Cape between mid-April and October. Although the bridge is owned by the U. S. Army Corps of Engineers, it is operated and maintained by personnel of the Bay Colony Railroad on a 100 percent reimbursable basis by the U. S. Army Corps of Engineers.

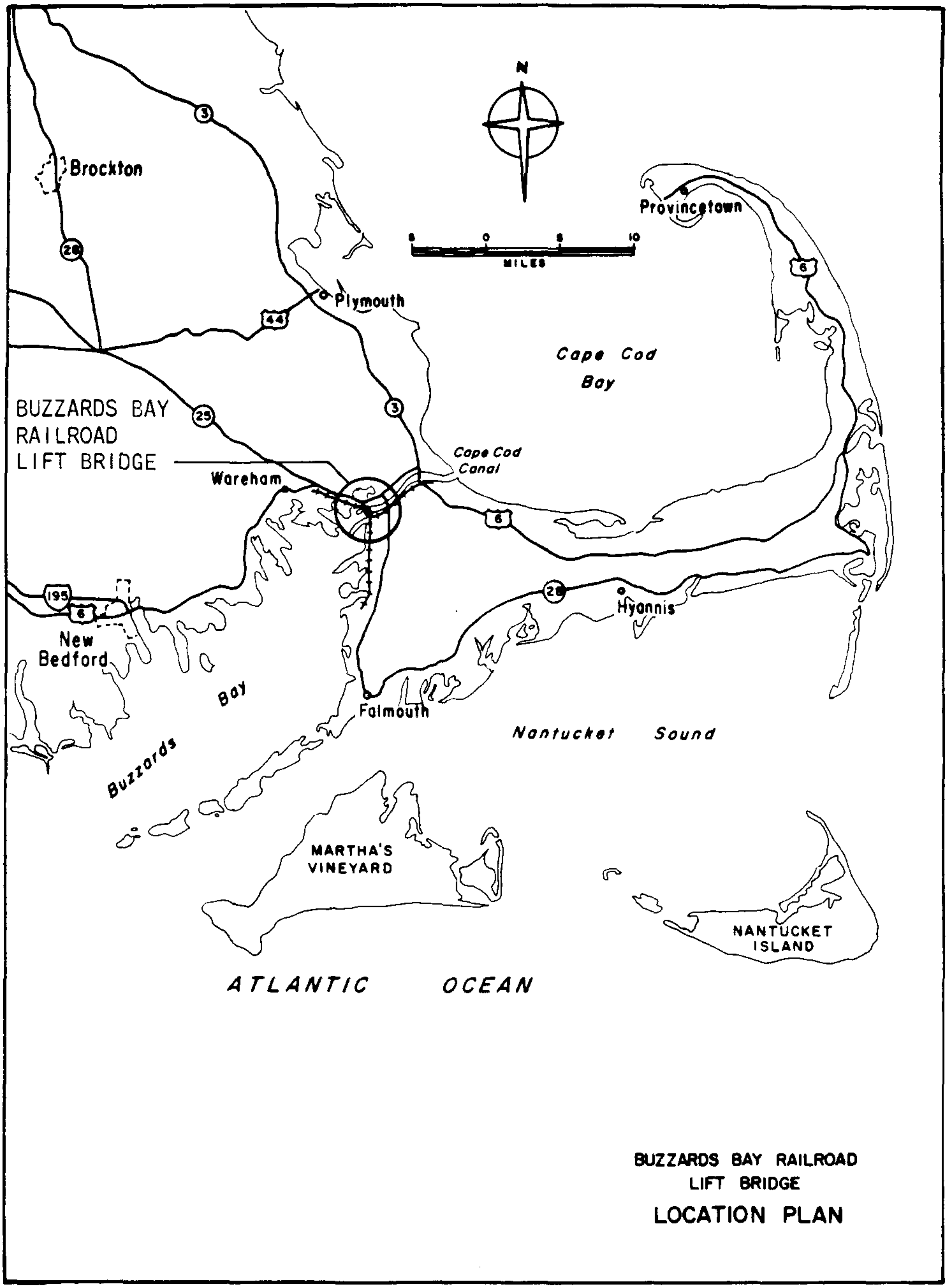

N
5 0 5 10
MILES
Brockton
Provincetown
Plymouth
Cape Cod
Bay
BUZZARDS BAY
RAILROAD
LIFT BRIDGE
Cape Cod
Canal
Wareham
New
Bedford
Hyannis
Bay
Buzzards
Falmouth
Nantucket Sound
MARTHA'S
VINEYARD
NANTUCKET
ISLAND
ATLANTIC OCEAN
3
28
44
25
6
195
BUZZARDS BAY RAILROAD
LIFT BRIDGE
LOCATION PLAN

FIGURE 1

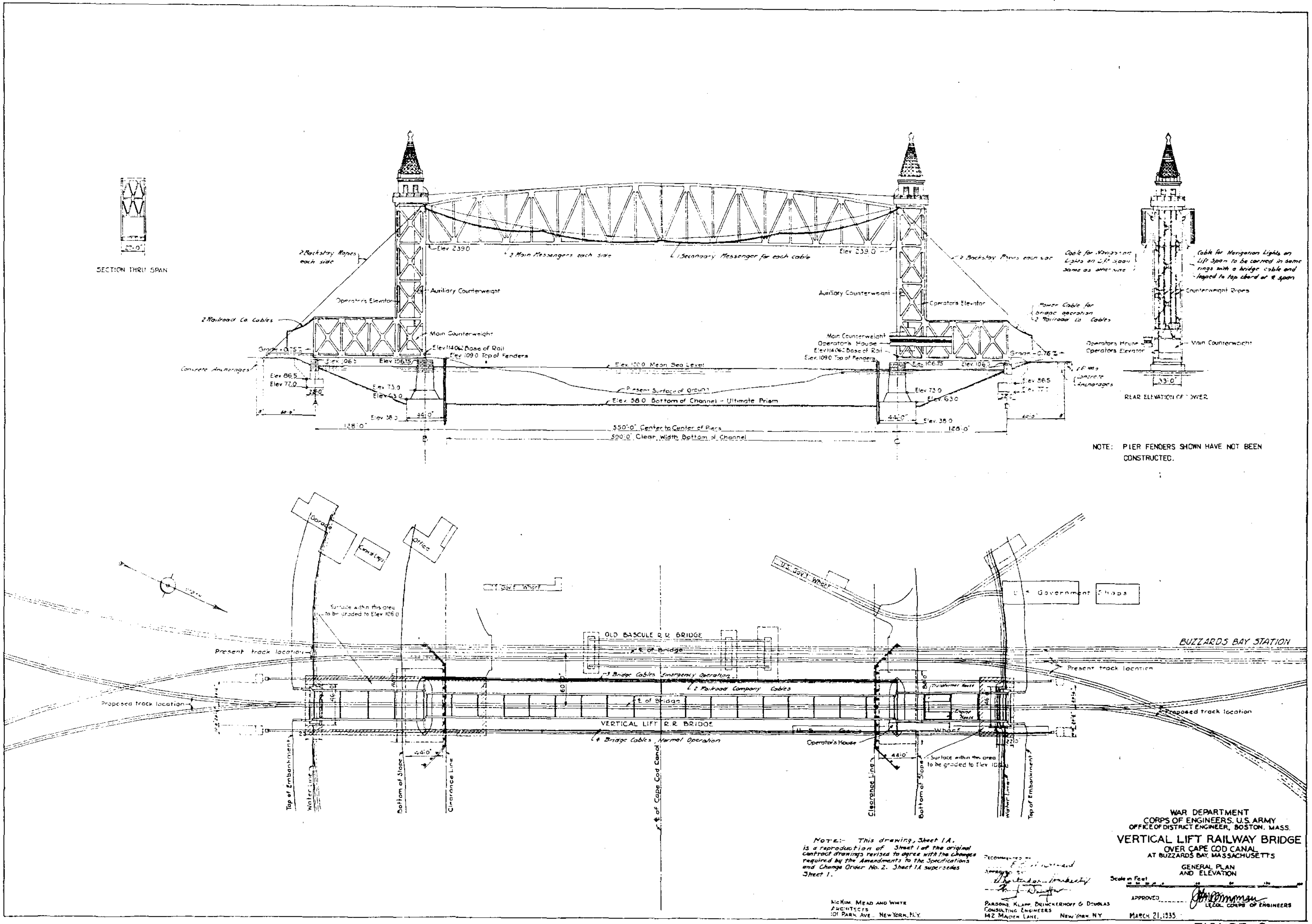

SECTION THRU SPAN
2 Backstay Ropes each side
2 Main Messengers each side
1 Secondary Messenger for each cable
Auxiliary Counterweight
Operators Elevator
2 Railroad Co. Cables
Main Counterweight
Operators House
Elev 100.0 Mean Sea Level
Present Surface of Ground
Elev 58.0 Bottom of Channel - Ultimate Prism
550'0" Center to Center of Piers
500'0" Clear Width Bottom of Channel
Concrete Anchorages
REAR ELEVATION OF TOWER
Counterweight Ropes
NOTE: PIER FENDERS SHOWN HAVE NOT BEEN CONSTRUCTED.
Garage
Office
U.S. Gov't. Wharf
U.S. Government Shops
OLD BASCULE R.R. BRIDGE
BUZZARDS BAY STATION
Present track location
Proposed track location
Surface within this area to be graded to Elev 106.0
2 Railroad Company Cables
VERTICAL LIFT R.R. BRIDGE
Bridge Cables Normal Operation
Operator's House
Top of Embankment
Water Line
Bottom of Slope
Clearance Line
℄ of Cape Cod Canal
NOTE:- This drawing, Sheet 1A, is a reproduction of Sheet 1 of the original contract drawings revised to agree with the changes required by the Amendments to the Specifications and Change Order No. 2. Sheet 1A supersedes Sheet 1.
McKIM, MEAD AND WHITE ARCHITECTS 101 PARK AVE., NEW YORK, N.Y.
PARSONS, KLAPP, BRINCKERHOFF & DOUGLAS CONSULTING ENGINEERS 142 MAIDEN LANE, NEW YORK, N.Y.
WAR DEPARTMENT
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF DISTRICT ENGINEER, BOSTON, MASS.
VERTICAL LIFT RAILWAY BRIDGE
OVER CAPE COD CANAL
AT BUZZARDS BAY, MASSACHUSETTS
GENERAL PLAN AND ELEVATION
Scale in Feet
APPROVED
LT. COL. CORPS OF ENGINEERS
MARCH 21, 1935

FIGURE 2

III. INSPECTION ORGANIZATION

On April 23, 1984, Modjeski and Masters received a Notice to Proceed with the project. An in-depth field inspection of the bridge was held during the following periods:

April 30 - May 18, 1984
June 4 - June 9, 1984
June 21, 1984

Mr. Joseph J. Scherrer was the Partner-in-Charge of the project, under whose general direction the entire inspection took place. Mr. Boyd P. Strain, Jr. was the Project Manager for both the field inspection and the subsequent evaluation and report phases of the project.

The following Modjeski and Masters' personnel participated in the inspection of the bridge:

Mr. Richard A. Little, P. E. - Field Project Engineer
Mr. Gary G. Cummings, P. E. - Engineer
Mr. Kenneth M. Kowalick, P. E. - Engineer
Mr. Michael F. Britt, EIT - Engineer
Mr. Lance V. Borden, P. E. - Electrical Engineer
Mr. Garry L. Fasick - Electrical Technician

Seven sub-consultants/sub-contractors were engaged by Modjeski and Masters to inspect those components of the structure which required specialized knowledge and skills. An eighth subcontractor was engaged to provide rigging for access to certain areas of the structure. The sub-consultants/sub-contractors participating in the inspection of the bridge were:

Milton C. Stafford, P. E., Consulting Mechanical Engineer
39 Union Avenue
Bala Cynwyd, Pennsylvania 19004

Arnold Greene Testing Laboratory/Division of Conam Inspection
6 Huron Drive
Natick, Massachusetts 01760
(617) 235-7330

Childs Engineering Corporation
Box 333
Medfield, Massachusetts 02052
(617) 359-8945

Cooper Energy Services
North Sandusky Street
Mount Vernon, Ohio 43050
(614) 397-0121

Weston Geophysical Corporation
Lyons Street
P. O. Box 550
Westboro, Massachusetts 01581
(617) 366-9191

Westinghouse Electric Corporation
Industry Services Divisions
New England Engineering Service
10 California Avenue
Framingham, Massachusetts 01701
(617) 237-6950

Cahn - Consulting Engineers and Planners
20 Alexander Drive
P. O. Box 767
Wallingford, Connecticut 06492
(203) 265-6741

George Campbell Painting Corporation
P. O. Box 631
40-11 149th Street
Flushing, New York 11352
(215) 353-8330

All of the structural steel superstructure components of the bridge and the above-water portions of the abutments and piers were inspected by Messrs. Little, Cummings, Kowalick and Britt. Most of the above-water structural inspection was made during the period April 30 - May 18, 1984. During the period between June 4 - 9, 1984, Messrs. Little and Cummings completed the superstructure inspection, including the tower metalwork and backstay cables. During both of the aforementioned periods, rigging and assistance was provided by personnel of the George Campbell Painting Corporation.

The underwater portion of the tower piers was inspected by engineer/divers provided by Childs Engineering Corporation. The underwater inspection was conducted on the days of May 8-10, and May 14-17, 1984 during the hours of slack water.

The abutments and the piers were surveyed horizontally and vertically, and the plumb of the towers was checked transversely and longitudinally by Cahn - Consulting Engineers and Planners. The surveying was performed on May 8, 9, 10 and June 21, 1984.

Vibration measurements were recorded on the lift span and at the top of the towers by Weston Geophysical Corporation on June 6 and 7, 1984.

Non-destructive (magnetic particle) testing for fatigue cracks and other defects was performed by Arnold Greene Testing Laboratory/Division of Conam Inspection on May 10, 1984.

The electrical equipment was inspected by Messrs. Borden and Fasick during the period April 30 - May 11, 1984. On May 2, 1984, personnel from Westinghouse Electric Corporation - Industry Services Division, inspected the oil-filled transformers and related switching gear, and obtained transformer oil samples for laboratory testing. The main emergency diesel generator was inspected and tested by personnel from Cooper Energy Services on May 8 and 9, 1984.

The mechanical equipment was inspected by Milton C. Stafford, P. E., Consulting Mechanical Engineer during the periods April 30 - May 18 and

June 4 - 9, 1984. A representative from the Torrington Company assisted with the inspection of the sheave roller bearings.

IV. MAINTENANCE HISTORY

A chronological history of major maintenance, repair and rehabilitation activities for the bridge is herein listed:

1940-1941	-	Cleaning and painting of superstructure.
1950-1952	-	Cleaning and painting of superstructure.
1954	-	Railroad tie replacement work, and installation of new diesel auxiliary generator begun.
1955	-	Railroad tie replacement work, construction of new generator house, installation of new diesel auxiliary generator completed, and installation of new power cables begun.
1956	-	Installation of new power cables completed, and generator house remodeled.
1957	-	Installation of fence around generator house.
1958-1960	-	Painting of superstructure.
1960-1961	-	Replacement of all main counterweight cables.
1966	-	Installation of new elevators and enclosures.
1967	-	Painting of superstructure.
1973-1974	-	Painting of superstructure.
1976-1977	-	Miscellaneous structural, electrical and mechanical repairs, modifications and rehabilitation. Replacement of main and secondary messenger cables. Repair of south backstay anchorage concrete.
1981-1982	-	Painting of superstructure.

V. INSPECTION FINDINGS AND RECOMMENDATIONS

A detailed discussion of the inspection findings is presented in the text of this report (Volume I). The report on the findings is divided in parts, with each part covering a major element of the bridge or specialized portion of the examination. Drawings, sketches and tables are included with each part of the report for reference. Recommendations for maintenance and repair or replacement of elements are presented in the respective parts. A complete summary of repair recommendations with priority ratings and estimated costs is presented in Part V-8.

Select colored photographs taken during the course of the examination to show typical or specific conditions are included herein. A majority of all the photographs showing general views of the bridge, the inspection procedures used throughout the work and general and specific conditions encountered are presented in a separate bound volume (Volume II). Photograph numbers referenced in the text are preceded with a Roman numerical indicating the volume in which they are included.

PART V-1

SUBSTRUCTURE

PART V-1 - SUBSTRUCTURE

The main substructure elements of the bridge consist of two reinforced concrete piers and two reinforced concrete abutments. The distance center-to-center of the piers is 550 feet and the centerline of the abutments is approximately 128 feet shoreward of the piers. Copies of the original contract drawings, showing the site topography and borings "as-built" configuration and the details of the substructure units, follow this part of the report as Figures 1-1, 1-2, 1-3 and 1-4.

The piers and abutments were originally designed to rest on spread footings at Elevations 38 and 77, respectively (refer to Figure 2). During construction, it was determined that the use of spread footings was not feasible, and the design was revised to place each substructure unit on oak bearing piles. The bottom of the pier footings was raised to Elevation 55; however, the bottom of the abutment footings remained at original design elevation. The piers and abutments are faced with granite for a distance of 5 feet above and 5 feet below mean sea level.

Reinforced concrete blocks, anchor the 1-1/4 inch diameter backstay and overhead main messenger cables for the bridge about 60 feet behind each abutment. Each of the four blocks is 8 feet wide, 8 feet high and 10 feet long. The bottom of the blocks are at Elevation 100.

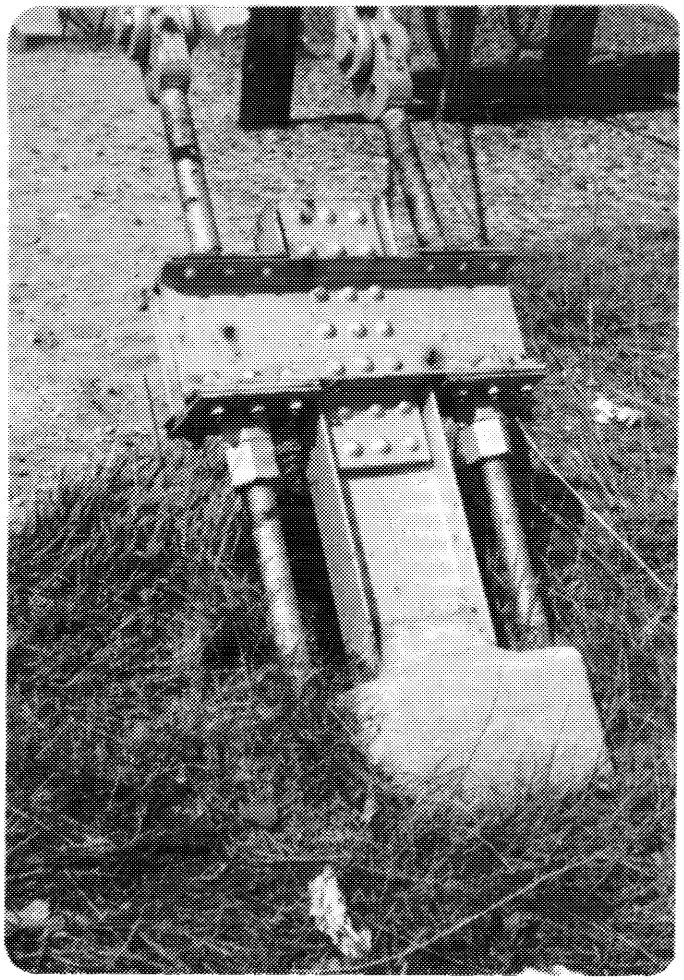
The main piers and abutments are designated as follows throughout the report.

Substructure Unit	Designation
South Abutment	A
South Pier	B
North Pier	C
North Abutment	D

Backstay Anchorages

The visible portions of the concrete cover at all four backstay anchorage units appear to be in good condition. Only minor hairline cracks or spalls were noted on the surfaces. The concrete cover on the two south anchorages was repaired in 1977. The northeast anchorage is encircled with cement block walls forming a pit. Minor cracks exist in the walls and debris is accumulating in the pit.

The visible elements of the anchorage metalwork are structurally sound. Surface corrosion exists on the metalwork of all four units (see Photograph I-2). Pitting, a maximum 1/16 to 3/32 inch deep, was noted in the webs of the longitudinal support beams of the north anchorages adjacent to the concrete embedment. Two 3/4 inch bolts, with beveled washers, are missing in the bottom flange of the lower transverse channel of the northeast anchorage and one other bolt is loose. A similar bolt and washer is missing at the southeast anchorage unit. Photographs II-28, 29 and 30 illustrate the other backstay anchorage units.



Photograph I-2 - Southwest backstay anchorage metalwork. Note typical corrosion.

Abutments

Abutments A and D remain in generally good condition. There are no indications of settlement or movement. The exposed concrete surfaces of the bearing seats, backwalls and wingwalls are somewhat rough from the long-term effects of the weather. At Abutment A, several hairline cracks traverse the bridge seat between the truss bearings. A crack about 1/32 inch wide exists in the concrete, approximately 6 feet east of the center rocker bearing. The mortar fill around the center bearing base plate is cracked, with sections displaced (see Photograph II-35).

A steel bracket, attached to each end of the Abutment D coping for support of a waterline, is severely deteriorated from corrosion.

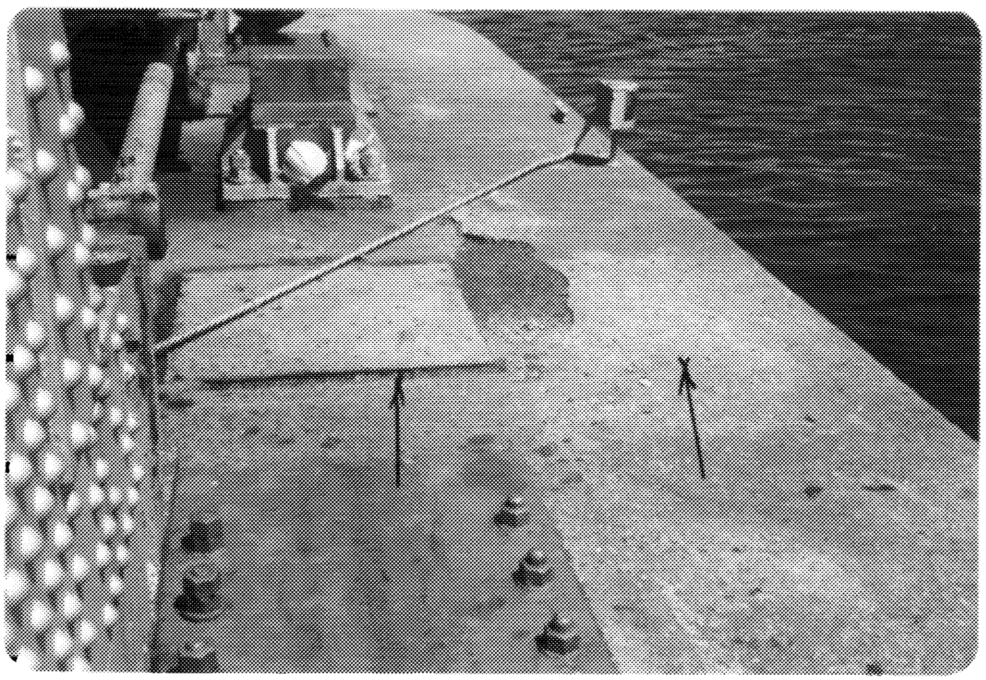
The granite facing on the abutments from the channel bottom to the coping concrete is sound. Short lengths of pointing are missing in the joints. Abutment A has about 6 feet of pointing missing from the horizontal joint below the upper course of granite and from a vertical joint on the west end. Approximately 4 feet of pointing is missing from the horizontal joint below the upper course of granite at the east end of Abutment D.

The canal bank adjacent to each abutment is protected by a satisfactory amount of rock riprap and there is no evidence of slope erosion above the protection. There are no locations where earth or rock fills are greater than provided for in the original design. Photographs II-31 through 34 and II-42, 43 and 44 illustrate the abutments.

Piers

Coping

The concrete coping of both piers was visually examined and sounded with hammers to determine deteriorated or unsound concrete areas. The horizontal concrete surfaces of both piers are spalled (1/2 to 1 inch deep), generally around bearing plates where moisture collects. A major spalled area exists in the northwest quadrant of the Pier B coping. No reinforcing is presently exposed at the spalled areas. Pier B has approximately 160 square feet and Pier C has about 96 square feet of deteriorating and unsound concrete. Transverse hairline cracks of minor significance exist in the upper surfaces of both piers. Figure 1-5 and Photographs I-3 and II-36, 40 and 41 show the spalled and unsound concrete areas on the pier tops.



Photograph I-3 - View of spalled and unsound areas on Pier C near west jacking plate.

The entrance to the submarine cable ducts on each pier is covered with a corrugated plate and secured with a lock bar. The angles of the support frames are corroded and the lock bar straps are severely laminated and bent upward, due to the forces of corrosion (see Photograph II-38). The heads of the eye-bolts securing the lock bar to the pier are separated at Pier C and have partial loss of section at Pier B.

Stem, Base and Cofferdam Sheeting

The granite facing above the water and the accessible underwater portions of the piers was visually examined by the divers. Several locations on the pier surfaces were cleaned of marine growth for closer examination of the surface. The soundness of the concrete was evaluated by striking the surface with a hammer. Thickness measurements of the sheet pile cofferdam surrounding the concrete base were recorded at selected elevations, using a Krautkramer D-Meter equipped with an underwater probe.

A brief presentation of the underwater findings is presented herein. The complete report of the underwater examination of the bridge piers, prepared by Childs Engineering Corporation, is included as Appendix E of this report. The photographs of the underwater inspection are included in Volume II.

Riprap stones, ranging in size from 12 to 18 inches, were noted on top of both pier concrete bases adjacent to the pier stem at Elevation 75.0. Heavy marine growth covers all portions of the piers from Elevation 100 to the mud line. The growth consists mainly of mussels and sponges, along with thin layers of algae. At some locations, the mussel growth is one foot thick. Between Elevation 100 and approximately Elevation 103, there is light barnacle growth on the granite facing.

The underwater concrete portions of the piers are in sound condition. No spalling, cracking or deterioration of the concrete stems was noted. The concrete was found to have a "soft" surface, 1/8 inch or less, when sounded with a hammer.

The cofferdam sheet piling is generally in good condition. Corrosion residue on the steel is 3/8 inch to 1/2 inch thick, with an outer layer of hard, crusty material. Below the outer layer, there are pockets of trapped gas accompanying a soft black layer of corrosion residue. The surfaces of the cleaned steel are slightly pitted with a maximum depth of less than 1/16 inch. Ultrasonic readings indicate average steel thicknesses of .330 inch (web) and .400 inch (flange) at Pier B, and .315 inch (web) and .390 inch (flange) at Pier C. The minimum thicknesses are .215 inch in a flange at Pier B and .205 inch in a flange at Pier C. The sheet piling was installed only as a method for constructing the piers, and now serves as protection for the concrete base. The loss of steel due to corrosion is not structurally significant.

Near the northeast corner of the Pier B cofferdam and the northwest corner of the Pier C cofferdam, the sheet pile wall appears to have been damaged by impact. Sections of sheet pile are bent over the top of the concrete base at Elevation 75 at both locations. Local crushing of the concrete base exists at these areas; however, no repairs are required.

Approximately 10 feet to the south of the southeast corner of Pier B cofferdam, three isolated sections of sheeting were not removed after construction. The top of these sheets are about Elevation 88 and may pose a problem for marine craft operating to the south of Pier B.

Along the west face of the Pier B cofferdam, there are seven 3 inch pipes leaning against the sheet pile wall. The pipes, spaced at approximately 2 feet centers, have no apparent function.

The cofferdam at Pier C has one split interlock along the channel face, approximately 20 feet to the west of the southeast corner. The base concrete, which is exposed at the separation, appears to be in sound condition.

The joints between the granite blocks of both piers are generally in excellent condition. At the east and west ends deteriorated grout exists in the horizontal joints below the first and second courses of granite from the top, to a maximum depth of 10 inches. Pier B has a total of 62 linear feet and Pier C a total of 50 linear feet of deteriorated joint grout.

Hydrographic Survey

Soundings were made of the channel bottom between the abutments and piers and on the channel side of each pier, using a white line recording fathometer. Nine runs were made on 25 foot centers parallel to the bridge (see Appendix E, Figure 597-84-6). Established elevations were used as a reference at the time of each run. Adjustments were then made, with the soundings shown on the drawing being referenced to mean low water (Elevation 98.3). The soundings were compared with a similar survey performed in 1971, with the results indicating there has been little or no change in the channel elevation.

On the channel side of Pier B, there is 7 to 9 feet of material between the channel bottom and bottom of footing. At Pier C, the depth is 9 to 15 feet. The depth of cover is satisfactory at both piers.

Alignment Survey

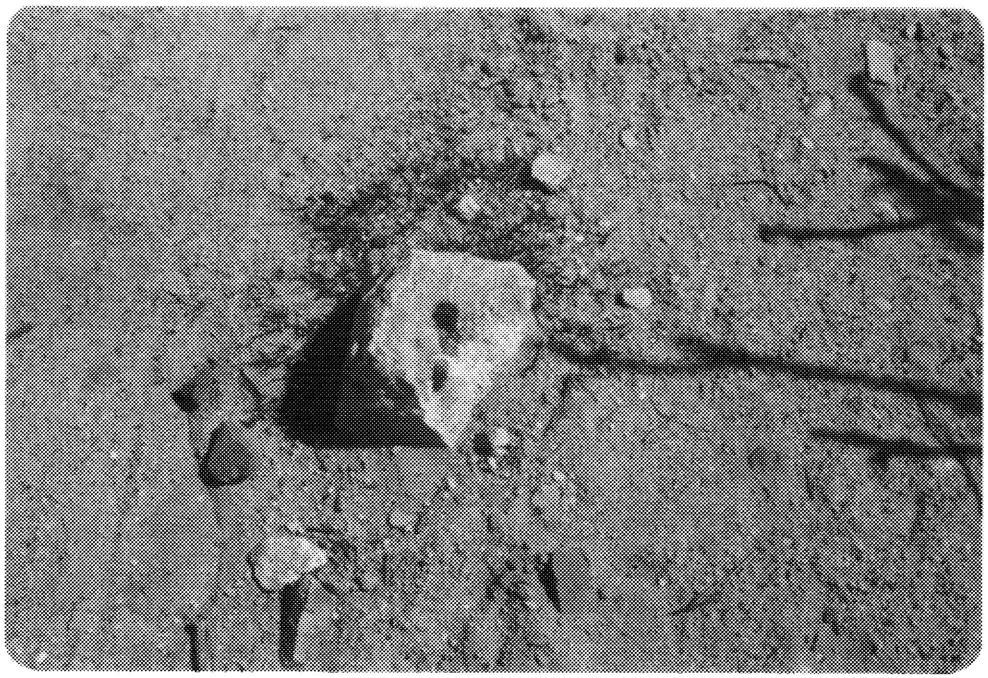
Since construction of the structure in 1935, the horizontal and vertical alignment of the piers and abutments have been checked by surveys at frequent intervals. The initial survey was performed in November and December, 1936, approximately one year after the bridge was placed in operation. The results of the surveys have been tabulated on a U. S. Army Corps of Engineers drawing entitled, "Railroad Bridge Alignment and Levels". A copy of this drawing, with the results of the 1984 survey, follows this part of the report as Figure 1-6.

Concrete monuments, with bronze plates, were established behind each abutment to provide two longitudinal reference lines across the bridge for the horizontal alignment surveys. Brass plugs were set on the longitudinal lines on each substructure unit near the ends. The two brass plugs set on the abutments are also used for elevation checks, while four additional plugs were set in each pier for elevation reference. Two are on bridge centerline and one is located near each nose. An additional concrete monument was established behind each abutment with a bronze plate to serve as a bench mark. Elevation checks on Abutment A and Pier B were most likely checked from the south bench mark (AA) and elevations on Pier C and Abutment D from the north bench mark (DD).

Horizontal Alignment

The brass plate in the southeast horizontal control monument (AE) was found missing and the top of the monument spalled (see Photograph I-4). The monument appears to be in the direct line of a bicycle and motor cycle path from an adjacent road along the Canal (refer to Photograph II-23).

Since Figure 1-6, showing the layout of the control monuments was not available at the time of the initial survey, a wooden plug was placed in the drill hole of the monument and a tack placed in the center of the plug for use as a reference point.



Photograph I-4 - Bronze plate is missing and the concrete is spalled on horizontal control Monument AE. Note adjacent bike tracks.

The changes in the monument reference distances, distances between piers and abutments and transverse offsets revealed by the surveys between 1936 and 1984 are shown on Figure 1-4. The comparison of results indicates little significant change, except for the transverse alignment on the east end of Abutment A and Pier B, the distances between Abutment A and both south control Monuments AE and AW and the distance between Abutment D and Monument DW. The above noted major changes in offsets and distances (9/16 to 1-7/16 inches) appear to be associated with movement of the control monuments and not the substructure units. Figure 1-6 indicates Monument DE had to be re-established in 1963 and Monument AW has possibly moved. The angles and distances of a traverse made of the four monuments has been added to Figure 1-4.

Vertical Alignment

A bench mark on the west edge of a small parking lot near the U. S. Army Corps of Engineers' boat dock was used for control of the elevation survey, since the original control information shown on Figure 1-6 was not initially available. The elevation of this control is 109.79 mean sea level. The resulting elevations on the abutments and piers when using the above bench mark were consistently over 1 inch higher than the elevations recorded in 1971. After the initial survey was completed, Figure 1-6 was located in the U. S. Army Corps of Engineers' office. A subsequent check between temporary bench marks of the original level run and Bench Marks AA and DD on the south and north sides of the Canal, revealed .083 feet and .119 feet, respective difference, in elevations. The 1984 elevations shown on Figure 1-6 are adjusted to the elevations shown for Bench Marks AA and DD.

The changes in the elevations recorded for the piers and abutments between 1936 and 1984 are shown on Figures 1-2 and 1-3. The substructure units appear to have risen an insignificant amount. The average of the change in elevations at each unit indicate a 1/8, 1/4, 3/8 and 5/16 inch rise of the respective substructure units A through D. No adverse affects on the superstructure should be realized by substructure movements of this magnitude.

Foundation Review

In addition to the alignment and level survey of the substructure units, the vertical alignment of each tower was checked. A transit was used to scan the edge of a column on each tower from locations on the canal banks. No perceptible deviation in the verticality of either tower was noted.

The findings of the underwater examination, hydrographic survey, alignment and level surveys, expansion bearing leans (see Part V-2) and alignment of the towers indicates that the piers and abutments are stable, with no significant settlement or longitudinal movement. A review of the original core borings shown on Figure 1-1 indicates that the development of future problems concerning the stability of substructure units is highly unlikely.

Recommendations

Backstay Anchorages

1. Replace two bolts and tighten a third fastener in the northeast anchorage metalwork. Replace a similar fastener at the southeast anchorage.

2. Trim vegetation at all units and remove debris from pit at northeast anchorage.

3. Thoroughly sandblast clean and paint metalwork.

Abutments

4. Replace the displaced and cracked mortar fill around the center bearing base plate on Abutment A.

5. Clean granite facing joints of loose mortar and replace about 6 and 4 linear feet of missing pointing at Abutments A and D, respectively.

6. Replace the two steel support brackets attached to the coping of Abutment D.

Piers

7. Repair spalled and unsound concrete areas on the horizontal and vertical surfaces of the pier copings.

8. Clean granite facing joints of loose mortar and replace about 62 and 50 linear feet of missing pointing at Piers B and C, respectively.

9. Burn off the three sections of sheet piling at the channel bottom at the southeast corner of Pier B.

10. Replace the lock bars and eye-bolt anchors for the corrugated covers over the submarine ducts in both piers.

Surveys

11. Establish new horizontal control Monuments AE and AW on the south side of the channel.

12. Continue periodic alignment, elevation and sounding checks for the bridge substructure.

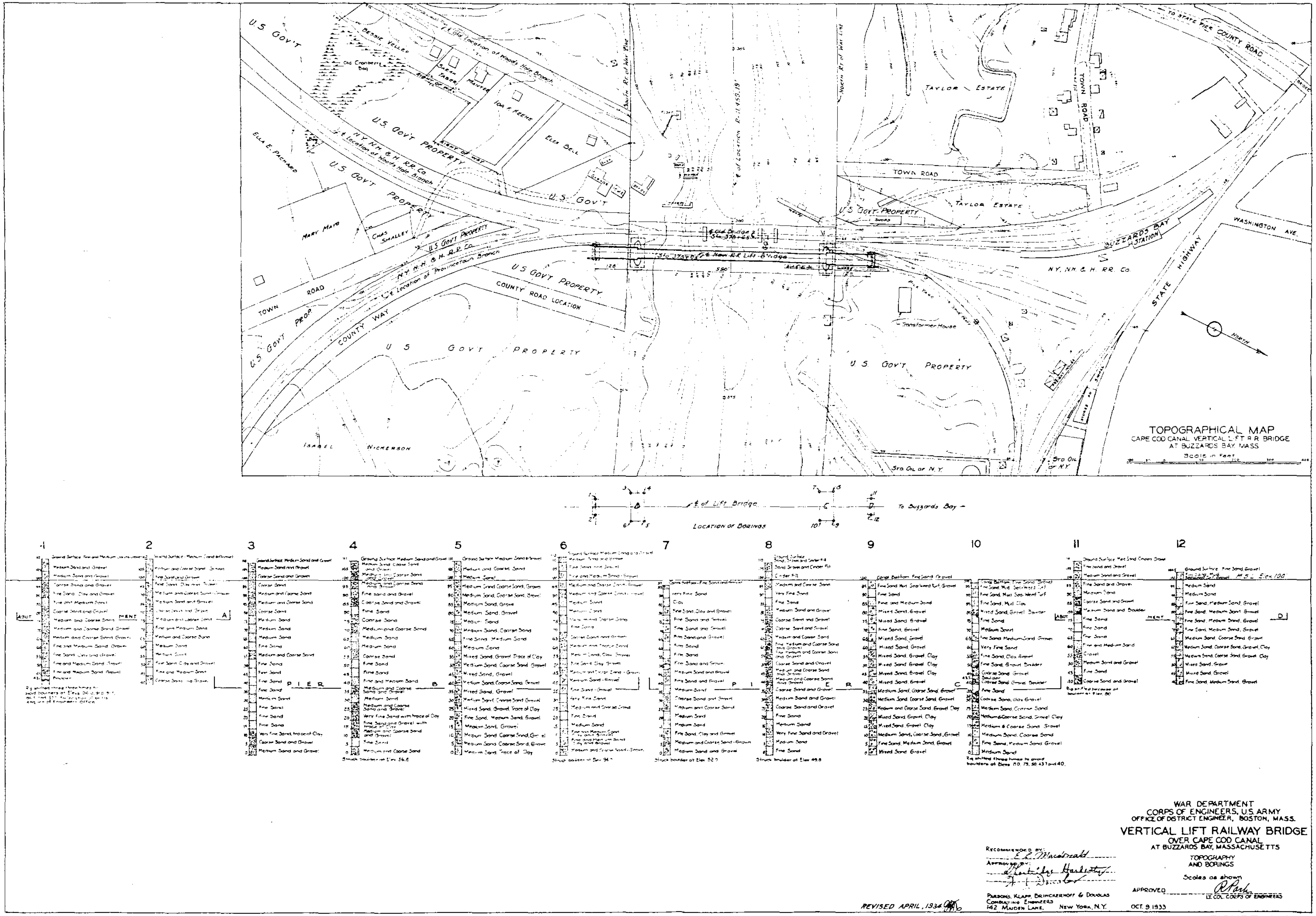
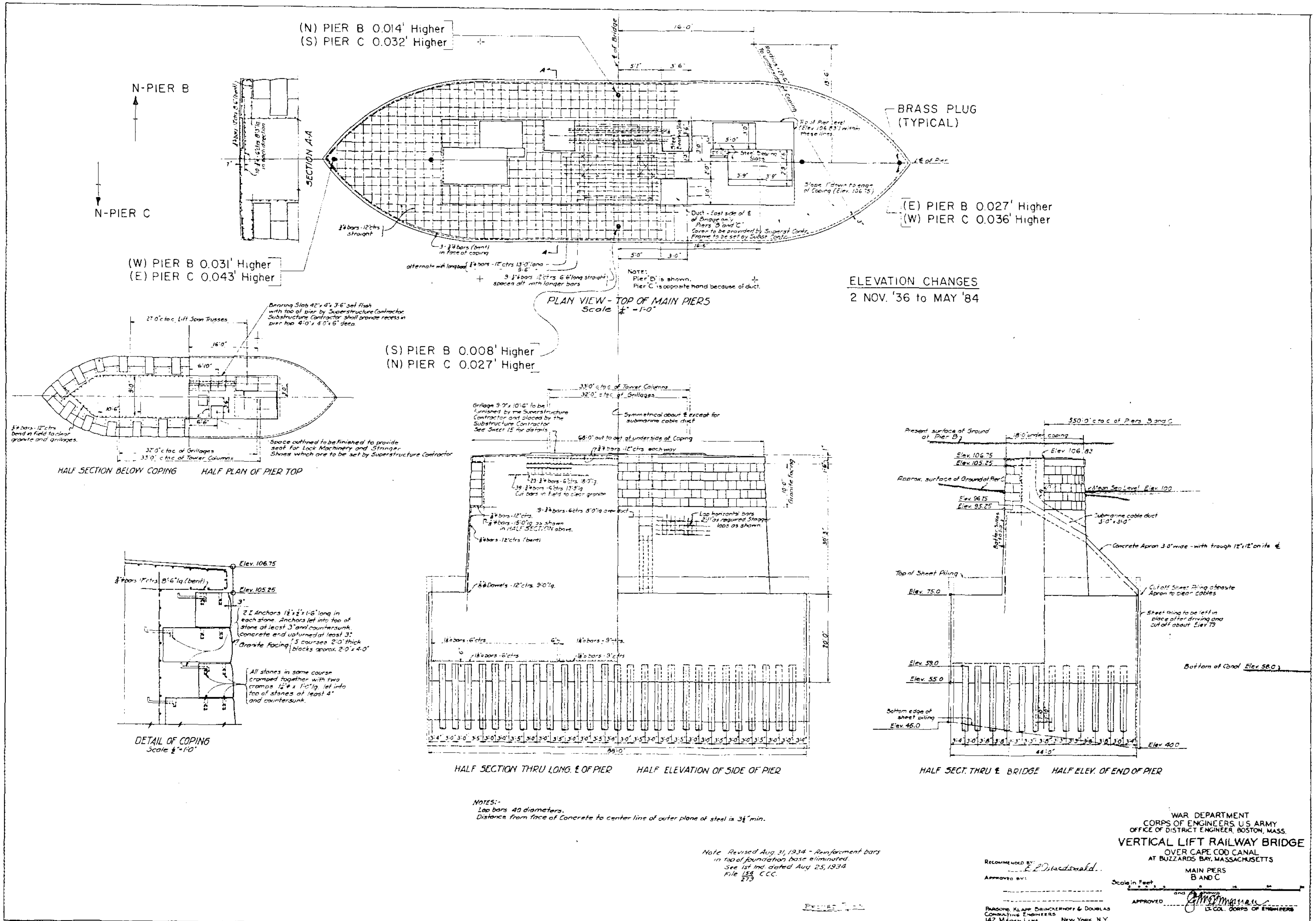
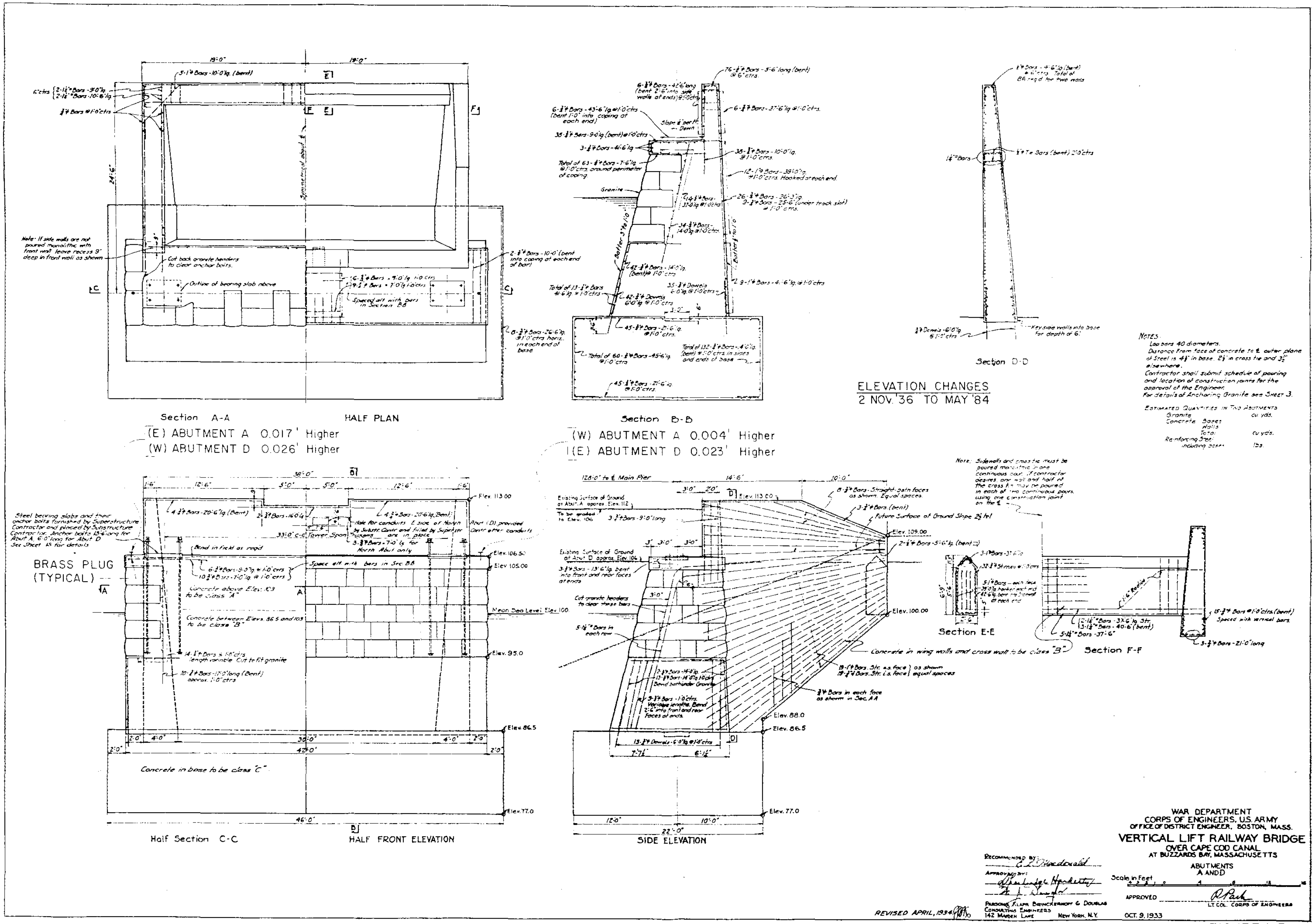

TOPOGRAPHICAL MAP
CAPE COD CANAL VERTICAL LIFT R.R. BRIDGE AT BUZZARDS BAY, MASS.
Scale in Feet
U.S. GOV'T PROPERTY
TAYLOR ESTATE
TOWN ROAD
COUNTY WAY
COUNTY ROAD LOCATION
STATE HIGHWAY
WASHINGTON AVE.
BUZZARDS BAY STATION
N.Y. N.H. & H. R.R. Co.
NORTH
Transformer House
ISABEL NICKERSON
MARY MAYO
ELLA E. PACKARD
Std. Oil of N.Y.
℄ of Lift Bridge
To Buzzards Bay
LOCATION OF BORINGS
ABUT MENT A
PIER B
PIER C
ABUT MENT D
WAR DEPARTMENT
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF DISTRICT ENGINEER, BOSTON, MASS.
VERTICAL LIFT RAILWAY BRIDGE
OVER CAPE COD CANAL
AT BUZZARDS BAY, MASSACHUSETTS
TOPOGRAPHY AND BORINGS
Scales as shown
RECOMMENDED BY:
APPROVED BY:
PARSONS, KLAPP, BRINCKERHOFF & DOUGLAS
CONSULTING ENGINEERS
142 MAIDEN LANE, NEW YORK, N.Y.
APPROVED
LT. COL. CORPS OF ENGINEERS
OCT. 9, 1933
REVISED APRIL, 1934

FIGURE 1-1



(N) PIER B 0.014' Higher
(S) PIER C 0.032' Higher
N-PIER B
N-PIER C
SECTION A-A
BRASS PLUG
(TYPICAL)
(E) PIER B 0.027' Higher
(W) PIER C 0.036' Higher
(W) PIER B 0.031' Higher
(E) PIER C 0.043' Higher
PLAN VIEW - TOP OF MAIN PIERS
ELEVATION CHANGES
2 NOV. '36 to MAY '84
(S) PIER B 0.008' Higher
(N) PIER C 0.027' Higher
HALF SECTION BELOW COPING
HALF PLAN OF PIER TOP
DETAIL OF COPING
HALF SECTION THRU LONG. ℄ OF PIER
HALF ELEVATION OF SIDE OF PIER
HALF SECT. THRU ℄ BRIDGE
HALF ELEV. OF END OF PIER
Bottom of Canal Elev. 58.0
NOTES:-
Lap bars 40 diameters.
Distance from face of Concrete to center line of outer plane of steel is 3½" min.
Note Revised Aug 31, 1934 - Reinforcement bars in top of foundation base eliminated.
See 1st Ind. dated Aug 25, 1934
WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
OFFICE OF DISTRICT ENGINEER, BOSTON, MASS.
VERTICAL LIFT RAILWAY BRIDGE
OVER CAPE COD CANAL
AT BUZZARDS BAY, MASSACHUSETTS
MAIN PIERS
B AND C
PARSONS, KLAPP, BRINCKERHOFF & DOUGLAS
CONSULTING ENGINEERS
142 MAIDEN LANE, NEW YORK, N.Y.
LT. COL. CORPS OF ENGINEERS

FIGURE I-2



Section A-A
HALF PLAN
(E) ABUTMENT A 0.017' Higher
(W) ABUTMENT D 0.026' Higher
Section B-B
(W) ABUTMENT A 0.004' Higher
(E) ABUTMENT D 0.023' Higher
Section D-D
ELEVATION CHANGES
2 NOV. '36 TO MAY '84
NOTES
BRASS PLUG
(TYPICAL)
Elev. 113.00
Elev. 106.50
Elev. 105.00
Mean Sea Level Elev. 100.
Elev. 95.0
Elev. 86.5
Elev. 77.0
Concrete in base to be class "C"
Half Section C-C
HALF FRONT ELEVATION
Section E-E
Section F-F
Elev. 109.00
Elev. 100.00
Elev. 88.0
SIDE ELEVATION
REVISED APRIL, 1934
WAR DEPARTMENT
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF DISTRICT ENGINEER, BOSTON, MASS.
VERTICAL LIFT RAILWAY BRIDGE
OVER CAPE COD CANAL
AT BUZZARDS BAY, MASSACHUSETTS
ABUTMENTS
A AND D
Scale in Feet
APPROVED
LT. COL. CORPS OF ENGINEERS
OCT. 9, 1933
Parsons, Klapp, Brinckerhoff & Douglas
Consulting Engineers
142 Maiden Lane New York, N.Y.

FIGURE I-3

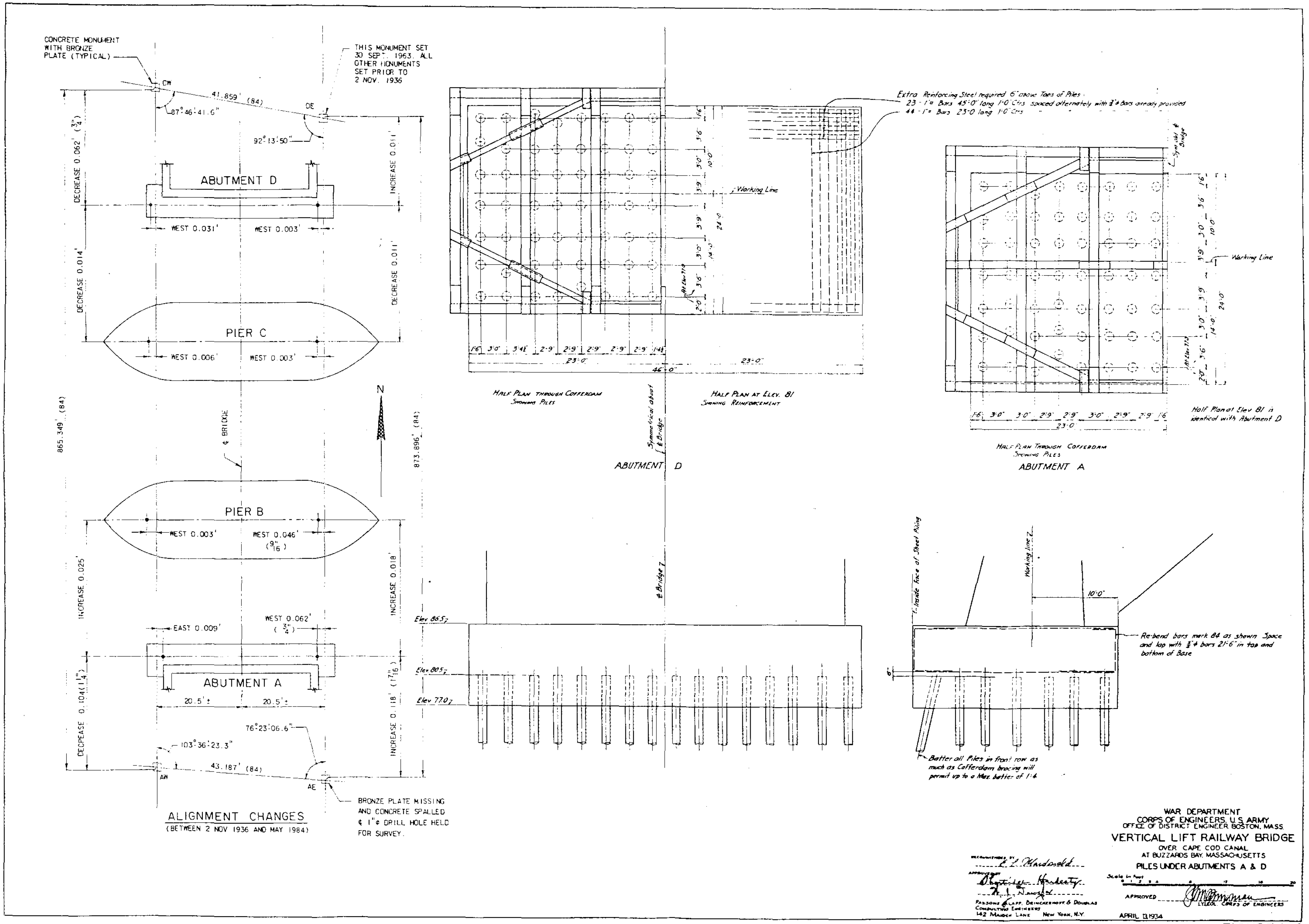
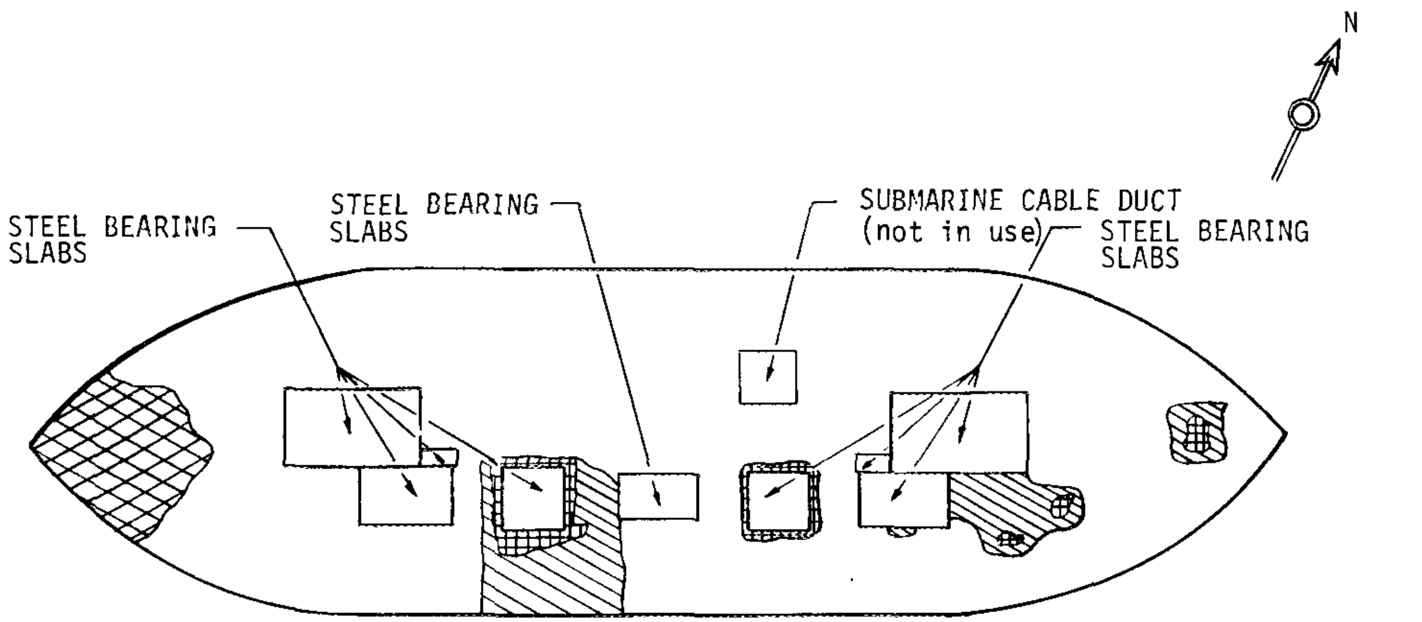

CONCRETE MONUMENT WITH BRONZE PLATE (TYPICAL)
THIS MONUMENT SET 30 SEPT. 1963. ALL OTHER MONUMENTS SET PRIOR TO 2 NOV. 1936
ABUTMENT D
PIER C
PIER B
ABUTMENT A
ALIGNMENT CHANGES
(BETWEEN 2 NOV 1936 AND MAY 1984)
BRONZE PLATE MISSING AND CONCRETE SPALLED ¢ 1"¢ DRILL HOLE HELD FOR SURVEY.
Half Plan through Cofferdam Showing Piles
Half Plan at Elev. 81 Showing Reinforcement
ABUTMENT D
Half Plan through Cofferdam Showing Piles
ABUTMENT A
Half Plan at Elev 81 is identical with Abutment D
Extra Reinforcing Steel required 6" above Toes of Piles
Working Line
Re-bend bars mark 84 as shown. Space and lap with ¾"¢ bars 21'-6" in top and bottom of Base
Batter all Piles in front row as much as Cofferdam bracing will permit up to a Max. batter of 1:4
WAR DEPARTMENT
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF DISTRICT ENGINEER BOSTON, MASS.
VERTICAL LIFT RAILWAY BRIDGE
OVER CAPE COD CANAL
AT BUZZARDS BAY, MASSACHUSETTS
PILES UNDER ABUTMENTS A & D
APPROVED
APRIL 13, 1934
Parsons, Klapp, Brinckerhoff & Douglas
Consulting Engineers
142 Maiden Lane New York, N.Y.

FIGURE I-4



PLAN VIEW TOP OF PIER C

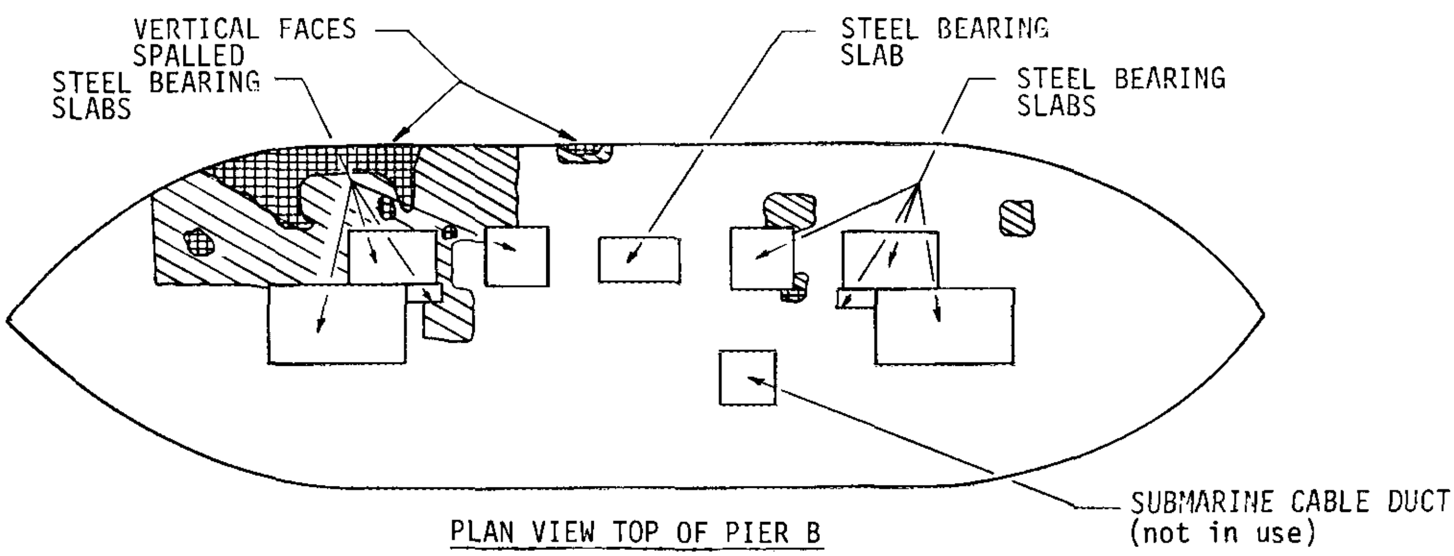
LEGEND

SPALLED CONCRETE

UNSOUND CONCRETE

SCALED PIERTOP SEALER

SCALE: 3/32" = 1'-0"



PLAN VIEW TOP OF PIER B

FIGURE 1-5

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

See Notes — (rows of 11 June 56, C.M. buried)

Conc. Mon. Established 30 Sept. 1963

Upper tables

DATE	DISTANCE	MOVEMENT PERD	TO DATE
2 Nov 36	44.657	.000	.000
30 Apr 46	44.664		+.007
7 Nov 46	44.661	-.003	+.004
2 July 47	44.658	-.003	+.001
17 June 48	44.659	+.001	+.002
23 Aug 49	44.658	-.001	+.001
11 June 56	C.M. buried		
"	"		
Conc. Mon. Buried			
1 Oct 1963	25.190		
18 Aug 64	25.173	-.017	-.017
20 Aug 65	25.173	.000	-.017
23 Aug 66	25.164	-.009	-.026
Oct '67	25.182	+.018	-.008
4 Sept 68	25.179	-.003	-.011
2 Oct 69	25.179	.000	-.011
5 Oct 70	25.211	+.032	+.021
29 Sept 71	25.214	+.003	+.024
May 84	25.201	-.013	+.011

DATE	ELEVAT'N	SETTLEM'T PERD	TO DATE
3 Nov 36	106.464	.000	.000
30 Apr 46	106.468		+.004
4 Nov 46	106.456	-.012	-.008
10 July 47	106.464	+.008	.000
15 June 48	106.465	+.001	+.001
13 July 49	106.462	-.003	-.002
24 Sept 51	106.462	.000	-.002
10 Mar 52	106.466	+.004	+.002
17 July 53	106.467	+.001	+.003
17 May 56	106.487	+.020	+.023
5 June 57	106.485	-.002	+.021
18 Aug 58	106.487	+.002	+.023
21 July 59	106.484	-.002	+.020
14 Nov 60	106.479	-.005	+.015
26 Dec 61	106.483	+.004	+.019
19 Sept 63	106.484	+.001	+.020
15 Sept 64	106.487	+.003	+.023
12 Aug 66	106.485	-.002	+.021
21 Aug 67	106.485	.000	+.021
5 Sept 68	106.486	+.001	+.022
2 Oct 69	106.485	-.001	+.021
27 Aug 70	106.485	-.003	+.019
22 Sept 71	106.484	-.001	+.018
May 84	106.489	+.005	+.023

DATE	ALIGNMENT WEST OF	EAST OF
3 Nov 36	.000	.000
30 Apr 46	.000	.000
4 Nov 46	.000	.000
2 July 47	.000	.000
17 June 48	.000	.000
13 July 49	.000	.000
11 June 56	C.M. buried	
"	"	
5 June 57	.000	.000
20 Aug 58	* .000	.000
19 Aug 59	* .000	.000
Conc. Mon. Buried		
1 Oct 1963	—	.003
18 Aug 64	.000	.002
20 Aug 65		
23 Aug 66	.004	
Oct '67		.003
4 Sept 68		.002
2 Oct 69		.001
5 Oct 70		.009
29 Sept 71		.007
May 84	.003	

DATE	DISTANCE	MOVEMENT PERD	TO DATE
2 Dec 36	127.486	.000	.000
30 Apr 46	127.479		-.005
7 Nov 46	127.476	-.003	-.008
2 July 47	127.480	+.004	-.004
17 June 48	127.473	-.007	-.011
15 July 49	127.475	+.002	-.009
11 June 56	127.487	+.012	+.003
5 June 57	127.481	-.006	-.003
20 Aug 58	127.483	+.002	-.001
20 Oct 59	127.475	-.008	-.009
15 Dec 60	127.465	-.010	-.019
13 Aug 62	127.468	+.003	-.016
12 Aug 63	127.466	-.002	-.018
18 Aug 64	127.464	-.002	-.020
20 Aug 65	127.463	-.001	-.021
23 Aug 66	127.459	-.004	-.025
Oct 67	127.466	+.007	-.018
4 Sept 68	127.457	-.009	-.027
1 Oct 69	127.460	+.003	-.024
5 Oct 70	127.464	+.004	-.020
16 Nov 71	127.460	-.004	-.024
May 84	127.473	+.013	-.011

DATE	ELEVAT'N	SETTLEM'T PERD	TO DATE
3 Nov 36	106.765	.000	.000
30 Apr 46	Obstr.	In	Way
4 Nov 46	106.764	—	-.001
2 July 47	106.762	-.002	-.003
15 June 48	106.770	+.008	+.005
13 July 49	106.763	-.007	-.002
24 Sept 51	106.763	.000	-.002
10 Mar 52	106.764	+.001	-.001
17 July 53	106.771	+.007	+.006
17 May 56	106.789	+.018	+.024
5 June 57	106.784	-.005	+.019
18 Aug 58	106.786	+.002	+.021
21 July 59	106.789	+.003	+.024
14 Nov 60	106.786	-.003	+.021
26 Dec 61	106.786	.000	+.021
19 Sept 63	106.794	+.008	+.029
15 Sept 64	106.783	-.011	+.018
12 Aug 66	106.792	+.009	+.027
21 Aug 67	106.790	-.002	+.025
5 Sept 68	106.793	+.003	+.028
2 Oct 69	106.791	-.002	+.026
22 Sept 71	106.786	-.005	+.021
May 84	106.792	+.006	+.027

DATE	ELEVAT'N	SETTLEM'T PERD	TO DATE
3 Nov 36	106.720	.000	.000
30 Apr 46	106.727	+.007	+.007
4 Nov 46	106.722	-.005	+.002
30 July 47	106.723	+.001	+.003
15 June 48	106.727	+.004	+.007
13 July 49	106.728	+.001	+.008
24 Sept 51	106.727	-.001	+.007
10 Mar 52	106.724	-.003	+.004
17 July 53	106.724	.000	+.004
17 May 56	106.754	+.030	+.034
6 June 57	106.754	.000	+.034
18 Aug 58	106.754	.000	+.034
21 July 59	106.750	-.004	+.030
14 Nov 60	106.741	-.009	+.021
26 Dec 61	106.750	+.009	+.030
19 Sept 63	106.754	+.004	+.034
15 Sept 64	106.750	-.004	+.030
12 Aug 66	106.755	+.005	+.035
21 Aug 67	106.754	-.001	+.034
5 Sept 68	106.757	+.003	+.037
2 Oct 69	106.756	-.001	+.036
27 Aug 70	106.758	+.002	+.038
22 Sept 71	106.755	-.003	+.035
May 84	106.761	+.006	+.043

DATE	ALIGNMENT WEST OF	EAST OF
3 Nov 36	.000	.000
30 Apr 46	.000	.000
7 Nov 46	.000	.000
2 July 47	.000	.000
17 June 48	.000	.000
13 July 49	.000	.000
11 June 56	C.M. buried	
5 June 57	.014	.000
20 Aug 58	.008 *	.000 *
19 Aug 59	.006 *	.000
6 Dec 60	.007 *	
13 Aug 62	.005 *	
1 Oct 63	.007	
18 Aug 64	.006	
20 Aug 65		.001
23 Aug 66		.001
Oct 67	.003	
4 Sept 68	.000	.000
1 Oct 69	.003	
5 Oct 70	.001	
29 Sept 71		.009
May 84	.003	

DATE	ELEVAT'N	SETTLEM'T PERD	TO DATE
3 Nov 36	106.801	.000	.000
30 Apr 46	106.800		-.001
7 Nov 46	106.805	+.005	+.004
2 July 47	106.806	+.001	+.005
15 June 48	106.803	-.003	+.002
13 July 49	106.809	+.006	+.008
24 Sept 51	106.821	+.012	+.020
10 Mar 52	106.795	-.026	-.006
17 July 53	106.818	+.023	+.017
17 May 56	106.822	+.004	+.021
6 June 57	106.821	-.001	+.020
15 Aug 58	106.810	-.011	+.009
20 Aug 59	106.815	+.005	+.014
15 Nov 60	106.810	-.005	+.009
12 Oct 62	106.814	+.004	+.013
15 Aug 63	106.822	+.008	+.021
12 Aug 64	106.806	-.016	+.005
24 Aug 66	106.814	+.008	+.013
18 Oct 67	106.816	+.002	+.015
4 Sept 68	106.814	-.002	+.013
12 Sept 69	106.816	+.002	+.015
2 Oct 70	106.809	-.007	+.008
27 Sept 71			
May 84	106.815	+.006	+.014

DATE	ELEVAT'N	SETTLEM'T PERD	TO DATE
3 Nov 36	106.752	.000	.000
30 Apr 46	106.756		+.004
7 Nov 46	106.760	+.004	+.008
2 July 47	106.763	+.003	+.011
15 June 48	106.756	-.007	+.004
13 July 49	106.761	+.005	+.009
24 Sept 51	106.775	+.014	+.023
10 Mar 52	106.755	-.020	+.003
17 July 53	106.776	+.021	+.024
17 May 56	106.780	+.004	+.028
6 June 57	106.775	-.005	+.023
15 Aug 58	106.766	-.009	+.014
20 Aug 59	106.763	-.003	+.011
15 Nov 60	106.761	-.002	+.009
12 Oct 62	106.773	+.012	+.021
15 Aug 63	106.776	+.003	+.024
12 Aug 64	106.767	-.009	+.015
24 Aug 66	106.772	+.007	+.022
18 Aug 67	106.774	+.002	+.024
4 Sept 68	106.769	-.005	+.019
4 Sept 69	106.774	+.005	+.024
6 Oct 70	106.771	-.003	+.021
27 Sept 71	106.775	+.004	+.025
May 84	106.777	+.002	+.021

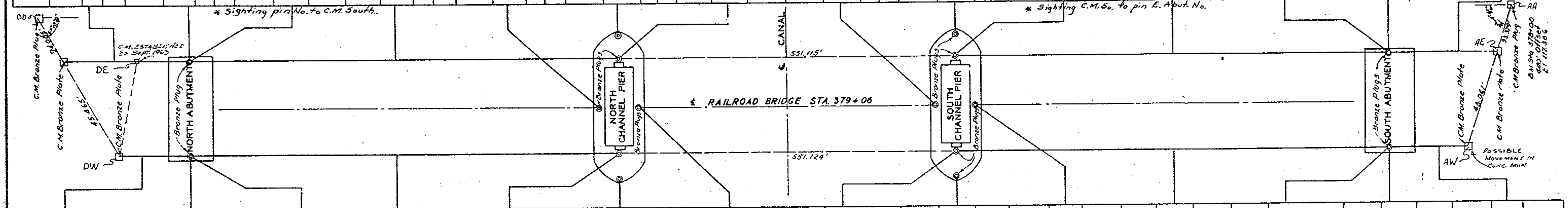
DATE	ALIGNMENT WEST OF	EAST OF
3 Nov 36	.000	.000
30 Apr 46	.000	.000
7 Nov 46	.000	.000
2 July 47	.000	.000
26 May 48	.000	.000
23 Aug 49	.000	.000
11 June 56	C.M. buried	
5 June 57	.000	.000
20 Aug 58	.014 *	.000
20 Aug 59	.011 *	.000
6 Dec 60	.016 *	
13 Aug 62	.011 *	
12 Aug 63	.010 *	
18 Aug 64	.010	
20 Aug 65	.019	
23 Aug 66	.019	
Oct 67	.040	
4 Sept 68	.040	
2 Oct 69	.030	
6 Oct 70	.008	
15 Nov 71	.020	
May 84	.046	

DATE	DISTANCE	MOVEMENT PERD	TO DATE
2 Dec 36	127.451	.000	.000
30 Apr 46	127.450		-.001
7 Nov 46	127.453	+.003	+.002
2 July 47	127.447	-.006	-.004
26 May 48	127.453	+.006	+.002
23 Aug 49	127.452	-.001	+.001
11 June 56	127.468	+.016	+.017
24 June 57	127.457	-.011	+.006
20 Aug 58	127.453	-.004	+.002
26 Oct 59	127.449	-.004	-.002
15 Dec 60	127.448	-.001	-.003
13 Aug 62	127.448	.000	-.003
15 Aug 63	127.453	+.005	+.002
18 Aug 64	127.441	-.011	-.009
20 Aug 65	127.447	+.006	-.004
23 Aug 66	127.440	-.007	-.011
Oct 67	127.439	-.001	-.012
4 Sept 68	127.443	+.004	-.008
2 Oct 69	127.439	-.004	-.012
5 Sept 70	127.462	+.023	+.011
15 Nov 71	127.477	+.015	+.026
May 84	127.469	-.008	+.018

DATE	ALIGNMENT WEST OF	EAST OF
3 Nov 36	.000	.000
30 Apr 46	.000	.000
7 Nov 46	.000	.000
2 July 47	.000	.000
26 May 48	.000	.000
23 Aug 49	.000	.000
11 June 56	C.M. buried	
5 June 67	.000	.000
20 Aug 58	.021 *	.000
20 Aug 59	.011 *	.000
6 Dec 60	.026 *	
13 Aug 62	.022 *	
27 Sept 63	.024 *	
18 Aug 64	.022	
20 Aug 65	.019	
23 Aug 66	.019	
Oct 67	.040	
4 Sept 68	.038	
2 Oct 69	.037	
6 Oct 70	.028	
15 Nov 71	.029	
May 84	.062	

DATE	ELEVAT'N	SETTLEM'T PERD	TO DATE
3 Nov 36	106.474	.000	.000
30 Apr 46	106.477		+.003
4 Nov 46	106.482	+.005	+.008
2 July 47	106.482	.000	+.008
26 May 48	106.479	-.003	+.005
13 July 49	106.479	.000	+.005
24 Sept 51	106.483	+.004	+.009
10 Mar 52	106.477	-.006	+.003
17 July 53	106.477	.000	+.003
17 May 56	106.484	+.007	+.010
6 June 57	106.482	-.002	+.008
15 Aug 58	106.480	-.002	+.006
20 Aug 59	106.482	+.002	+.008
15 Nov 60	106.479	-.003	+.005
12 Oct 62	106.480	+.001	+.006
15 Aug 63	106.484	+.004	+.010
12 Aug 64	106.481	-.003	+.007
24 Aug 66	106.484	+.003	+.010
18 Aug 67	106.483	-.001	+.009
4 Sept 68	106.484	+.001	+.010
12 Sept 69	106.483	-.001	+.009
6 Oct 70	106.483	.000	+.009
27 Sept 71	106.490	+.007	+.016
May 84	106.491	+.001	+.017

DATE	DISTANCE	MOVEMENT PERD	TO DATE
2 Nov 36	42.540	.000	.000
30 Apr 46	42.539		-.001
7 Nov 46	42.534	-.006	-.007
2 July 47	42.539	+.005	-.001
26 May 48	42.527	-.012	-.013
23 Aug 49	42.520	-.007	-.020
11 June 56	42.543	+.023	+.003
24 June 57	42.526	-.017	-.014
20 Aug 58	42.515	-.011	-.025
27 July 59	42.514	-.001	-.026
6 Dec 60	42.510	-.004	-.030
13 Aug 62	42.497	-.013	-.043
12 Aug 63	42.500	+.003	-.040
18 Aug 64	42.495	-.005	-.045
20 Aug 65	42.490	-.005	-.050
23 Aug 66	42.494	+.004	-.046
Oct 67	42.480	-.014	-.060
4 Sept 68	42.462	-.018	-.078
2 Oct 69	42.464	+.002	-.076
5 Sept 70	42.469	+.005	-.071
15 Nov 71	42.493	+.024	-.047
May 84	42.658	+.165	+.118



Lower tables

DATE	DISTANCE	MOVEMENT PERD	TO DATE
2 Nov 36	26.941	.000	.000
30 Apr 46	26.939		-.002
7 Nov 46	26.933	-.006	-.008
2 July 47	26.925	-.008	-.016
17 June 48	26.927	+.002	-.014
23 Aug 49	26.914	-.013	-.027
11 June 56	26.903	-.011	-.038
5 June 57	26.904	+.001	-.037
20 Aug 58	26.904	.000	-.037
28 July 59	26.906	+.002	-.035
7 Dec '59	26.903	-.003	-.038
13 Aug 62	26.904	+.001	-.037
12 Aug 63	26.902	-.002	-.039
18 Aug 64	26.900	-.002	-.041
20 Aug 65	26.856		
23 Aug 66	26.899	-.001	-.042
Oct 67	26.905	+.006	-.036
4 Sept 68	26.903	-.002	-.038
1 Oct 69	26.895	-.008	-.046
5 Oct 70	26.890	-.005	-.051
29 Nov 71	26.898	+.008	-.043
May 84	26.879	-.019	-.062

DATE	ELEVAT'N	SETTLEM'T PERD	TO DATE
3 Nov 36	106.463	.000	.000
30 Apr 46	106.463		.000
4 Nov 46	106.460	-.003	-.003
2 July 57	106.458	-.002	-.005
15 June 48	106.463	+.005	.000
13 July 49	106.461	-.002	-.002
24 Sept 51	106.458	-.003	-.005
10 Mar 52	106.463	+.005	.000
17 July 53	106.463	.000	.000
17 May 56	106.475	+.012	+.012
6 June 57	106.478	+.003	+.015
18 Aug 58	106.487	+.009	+.024
21 July 59	106.483	-.004	+.020
14 Nov 60	106.481	-.002	+.018
26 Dec 61	106.485	+.004	+.022
15 Aug 63	106.483	-.002	+.020
15 Sept 64	106.479	-.004	+.016
12 Aug 66	106.483	+.004	+.020
21 Aug 67	106.483	.000	+.020
5 Sept 68	106.484	+.001	+.021
2 Oct 69	106.484	.000	+.021
27 Aug 70	106.491	+.007	+.028
22 Sept 71	106.492	+.001	+.029
May 84	106.489	-.003	+.026

DATE	ALIGNMENT WEST OF	EAST OF
3 Nov 36	.000	.000
30 Apr 46	.000	.000
4 Nov 46	.000	.000
2 July 47	.000	.000
17 June 48	.000	.000
23 Aug 49	.000	.000
13 June 56	.007	.000
5 June 57	.010	.000
20 Aug 58	.000	.010
19 Aug 59	.011	.000
7 Dec 60	.017	.000
13 Aug 62	.018	—
12 Aug 63	.020	
18 Aug 64	.019	.000
20 Aug 65	.022	
23 Aug 66	.024	
Oct 67	.020	
4 Sept 68	.019	
1 Oct 69	.020	
5 Oct 70	.021	
29 Sept 71	.012	
May 84	.031	

DATE	DISTANCE	MOVEMENT PERD	TO DATE
2 Dec 36	127.415	.000	.000
30 Apr 46	127.410		-.005
7 Nov 46	127.405	-.005	-.010
2 July 47	127.400	-.005	-.015
17 June 48	127.413	+.013	-.002
23 Aug 49	127.403	-.010	-.012
11 June 56	127.416	+.013	+.001
5 June 57	127.411	-.005	-.004
20 Aug 58	127.430	+.019	+.015
20 Oct 59	127.406	-.024	-.009
15 Dec 60	127.399	-.007	-.016
13 Aug 62	127.397	-.002	-.018
12 Aug 63	127.398	+.001	-.017
18 Aug 64	127.395	-.003	-.020
20 Aug 65	127.393	-.002	-.022
23 Aug 66	127.405	+.012	-.010
Oct 67	127.403	-.002	-.012
4 Sept 68	127.386	-.017	-.029
1 Oct 69	127.394	+.008	-.021
5 Oct 70	127.408	+.014	-.007
15 Nov 71	127.392	-.016	-.023
May 84	127.401	+.009	-.014

DATE	ALIGNMENT WEST OF	EAST OF
3 Nov 36	.000	.000
30 Apr 46	.000	.000
7 Nov 46	.000	.000
2 July 47	.000	.000
15 June 48	.000	.000
23 Aug 49	.000	.000
13 June 56	.009	.000
5 June 57	.009	.000
20 Aug 58	.009	.012
19 Aug 59	.011	.000
7 Dec 60	.013	.000
13 Aug 62	.015	.000
12 Aug 63	.016	
18 Aug 64	.019	.000
20 Aug 65	.017	
23 Aug 66	.016	
Oct 67	.016	
4 Sept 68	.008	
1 Oct 69	.018	
5 Oct 70	.009	
29 Sept 71	.010	
May 84	.006	

DATE	ELEVAT'N	SETTLEM'T PERD	TO DATE
3 Nov 36	106.705	.000	.000
30 Apr 46	106.707		+.002
4 Nov 46	106.708	+.001	+.003
2 July 48	106.707	-.001	+.002
15 June 48	106.708	+.001	+.003
13 July 49	106.711	+.003	+.006
24 Sept 51	106.729	[illegible]	[illegible]
10 Mar 52	106.706	[illegible]	[illegible]
17 July 53	106.715	[illegible]	[illegible]
17 May 56	106.733	+.018	+.028
6 June 57	106.735	+.002	+.030
18 Aug 58	106.730	-.005	+.025
21 July 59	106.734	+.004	+.029
14 Nov 60	106.735	+.001	+.030
26 Dec 61	106.742	+.007	+.037
15 Aug 63	106.747	+.005	+.042
15 Sept 64	106.734	-.013	+.029
22 Aug 66	106.738	+.004	+.033
21 Aug 67	106.739	+.001	+.034
4 Sept 68	106.741	+.002	+.036
2 Oct 69	106.738	-.003	+.033
27 Aug 70	106.740	+.002	+.035
22 Sept 71	106.744	+.004	+.039
May 84	106.741	-.003	+.036

DATE	ELEVAT'N	SETTLEM'T PERD	TO DATE
3 Nov 36	106.730	.000	.000
30 Apr 46	106.737		+.007
4 Nov 46	106.730	-.007	.000
2 July 47	106.728	-.002	-.002
15 June 48	Obstruction		
13 July 49	106.732	+.004	+.002
24 Sept 51	106.740	+.008	+.010
10 Mar 52	106.732	-.008	+.002
17 July 53	106.735	+.003	+.005
17 May 56	106.757	+.022	+.027
6 June 57	106.759	+.002	+.029
18 Aug 58	106.753	-.006	+.023
21 July 59	106.757	+.004	+.027
14 Nov 60	106.755	-.002	+.025
26 Dec 61	106.754	-.001	+.024
15 Aug 63	106.771	+.017	+.041
15 Sept 64	106.762	-.009	+.032
12 Aug 66	106.759	-.003	+.029
21 Aug 67	106.755	-.004	+.025
4 Sept 68	106.760	+.005	+.030
2 Oct 69	106.758	-.002	+.028
22 Sept 71	106.756	-.002	+.026
May 84	106.762	+.006	+.032

DATE	ALIGNMENT WEST OF	EAST OF
30 Nov 36	.000	.000
30 Apr 46	.000	.000
7 Nov 46	.000	.000
2 July 47	.000	.000
26 May 48	.000	.000
23 Aug 49	.000	.000
13 June 56	.004	.000
5 June 57	.000	.000
6 Dec 60	.003	.000
13 Aug 62	.000	.000
12 Aug 63	.000	.000
12 Aug 64	.007	
20 Aug 65	.002	
23 Aug 66	.000	.000
Oct 67	.000	
4 Sept 68	.001	
2 Oct 69	.003	
5 Sept 70		.001
15 Nov 71		.009
May 84	.003	

DATE	ELEVAT'N	SETTLEM'T PERD	TO DATE
3 Nov 36	106.750	.000	.000
30 Apr 46	106.751		+.001
7 Nov 46	106.757	+.006	+.007
2 July 47	106.758	+.001	+.008
15 June 48	106.752	-.006	+.002
13 July 49	106.760	+.008	+.010
24 Sept 51	106.775	+.015	+.025
10 Mar 52	106.755	-.020	+.005
17 July 53	106.768	+.013	+.018
17 May 56	106.777	+.009	+.027
6 June 57	106.774	-.003	+.024
15 Aug 58	106.760	-.014	+.010
20 Aug 59	106.767	+.007	+.017
15 Nov 60	106.753	-.014	+.003
12 Oct 62	106.772	+.019	+.022
16 Aug 63	106.772	.000	+.022
12 Aug 64	106.762	-.010	+.012
24 Aug 66	106.769	+.007	+.019
18 Aug 67	106.771	+.002	+.021
4 Sept 68	106.763	-.008	+.013
12 Sept 69	106.762	-.001	+.012
2 Oct 70	106.766	+.004	+.016
27 Sept 71	106.772	+.006	+.022
May 84	106.781	+.009	+.031

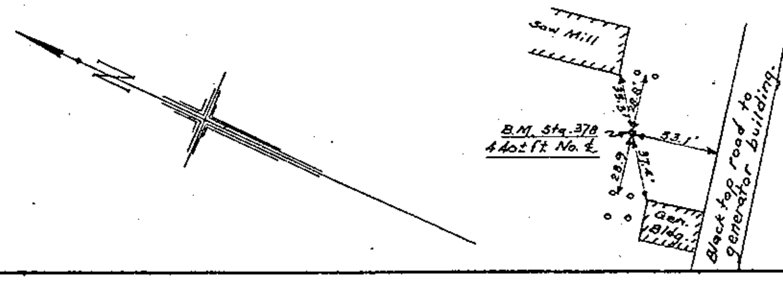
DATE	ELEVAT'N	SETTLEM'T PERD	TO DATE
3 Nov 36	106.791	.000	.000
30 Apr 46	Obstruction in way		
4 Nov 46	106.800		+.009
2 July 47	106.801	+.001	+.010
15 June 48	106.795	-.006	+.004
13 July 49	106.804	+.009	+.013
24 Sept 51	106.813	+.009	+.022
10 Mar 52	106.793	-.020	+.002
17 July 53	106.810	+.017	+.019
17 May 56	Sheet metal in way		
15 Aug 58	106.808	-.002	+.017
20 Aug 59	106.809	+.001	+.018
15 Nov 60	106.798	-.011	+.007
12 Oct 62	106.809	+.011	+.018
15 Aug 63	106.812	+.003	+.021
12 Aug 64	106.799	-.013	+.008
24 Aug 66	106.809	+.010	+.018
18 Aug 67	106.811	+.002	+.020
5 Sept 68	106.808	-.003	+.017
12 Sept 69	106.811	+.003	+.020
2 Oct 70	106.797	-.014	+.006
May 84	106.799	+.002	+.008

DATE	DISTANCE	MOVEMENT PERD	TO DATE
2 Dec 36	127.498	.000	.000
30 Apr 46	127.498		.000
7 Nov 46	127.507	+.009	+.009
2 July 47	127.505	-.002	+.007
15 June 48	127.500	-.005	+.002
23 Aug 49	127.499	-.001	+.001
13 June 56	127.521	+.022	+.023
24 June 57	127.505	-.016	+.007
20 Aug 58	127.519	+.014	+.021
26 Oct 59	127.505	-.014	+.007
15 Dec 60	127.491	-.014	-.007
13 Aug 62	127.500	+.009	+.002
15 Aug 63	127.499	-.001	+.001
18 Aug 64	127.497	-.002	-.001
20 Aug 65	127.496	-.001	-.002
23 Aug 66	127.490	-.006	-.008
18 Aug 67	127.504	+.014	+.006
4 Sept 68	127.501	-.003	+.003
2 Oct 69	127.495	-.006	-.003
5 Oct 70	127.514	+.019	+.016
15 Nov 71	127.500	-.014	+.002
May 84	127.523	+.023	+.025

DATE	ALIGNMENT WEST OF	EAST OF
3 Nov 36	.000	.000
30 Apr 46	.000	.000
7 Nov 46	.000	.000
2 July 47	.000	.000
26 May 48	.000	.000
23 Aug 49	.000	.000
13 June 56	.004	.000
5 June 57	.000	.000
20 Aug 58	.000	.000
20 Aug 59	.004	.000
6 Dec 60	.003	
13 Aug 62	.003	.000
27 Sept 63	.000	
18 Aug 64	.002	
20 Aug 65	.003	
23 Aug 66	.003	
Oct 67	.003	
4 Sept 68	.002	
2 Oct 69	.002	
5 Sept 70	.000	
15 Nov 71	.001	
May 84		.009

DATE	ELEVAT'N	SETTLEM'T PERD	TO DATE
3 Nov 36	106.483	.000	.000
30 Apr 46	106.483		.000
4 Nov 46	106.490	+.007	+.007
2 July 47	106.496	+.006	+.013
15 June 48	106.489	-.007	+.006
13 June 49	106.493	+.004	+.010
24 Sept 51	106.501	+.008	+.018
10 Mar 52	106.486	-.015	+.003
17 July 53	106.496	+.010	+.013
17 May 56	106.505	+.009	+.022
6 June 57	106.506	+.001	+.023
15 Aug 58	106.496	-.010	+.013
20 Aug 59	106.495	-.001	+.012
15 Nov 60	106.479	-.016	-.004
12 Oct 62	106.498	+.019	+.015
16 Aug 63	106.495	-.003	+.012
12 Aug 64	106.484	-.011	+.001
18 Aug 67	106.497	+.013	+.014
4 Sept 68	106.491	-.006	+.008
12 Sept 69	106.483	-.008	.000
2 Oct 70	106.491	+.008	+.008
27 Sept 71	106.489	-.002	+.006
May 84	106.487	-.002	+.004

DATE	DISTANCE	MOVEMENT PERD	TO DATE
2 Nov 36	32.548	.000	.000
30 Apr 46	32.525		-.023
7 Nov 46	32.521	-.004	-.027
2 July 47	32.514	-.007	-.034
15 June 48	32.511	-.003	-.037
23 Aug 49	32.508	-.003	-.040
12 June 56	32.487	-.021	-.061
13 June 57	32.507	+.020	-.041
20 Aug 58	32.490	-.017	-.058
29 July 59	32.496	+.006	-.052
6 Dec 60	32.493	-.003	-.055
13 Aug 62	32.480	-.013	-.068
12 Aug 63	32.480	.000	-.068
18 Aug 64	32.479	-.001	-.069
20 Aug 65	32.477	-.002	-.071
23 Aug 66	32.488	+.011	-.060
Oct 67	32.485	-.003	-.063
4 Sept 68	32.476	-.009	-.072
2 Oct 69	32.477	+.001	-.071
6 Oct 70	32.478	+.001	-.070
15 Nov 71	32.461	-.017	-.087
May 84	32.444	-.017	-.104



17 May 1956 ~~Center~~ Center punch on bent over brass pin.
15 June 1948 ~~103.956~~ after damage.

BENCH MARK ELEV. ~~105.972~~ 107.944 **
Sta. 378+00 440 ft. North of ℄ of Canal. Bronze plug top of Concrete Monument. Monument top 16"x16" Bottom 24"x24" length 6'. Bottom of monument is 5½' below surface of ground. Bench Mark established Nov. 3, 1936. Disturbed and reset in July 1939 El. 105.972
New top and pin set in Aug. 1956. **

BENCH MARK ELEV. 117.386
Sta. 378+00 440 ft. South of ℄ of Canal. Bronze plug top of Concrete Monument. Monument top 10"x10". Bottom 24"x24" length 8'. Bottom of monument is 7½' below surface of ground. Bench Mark Established Nov. 2, 1936.

PRIMARY BENCH MARK ELEV. 111.780
Sta. 382+38, 920 ft. South of ℄ of Canal. Bronze pin N.E. corner concrete foundation of U.S. Engineer Department pump house. Bench Mark established Sept. 1935.

NOTE
Bench Marks are referred to Cape Cod Canal Base (Mean Sea Level = Elevation 100.0)
Bridge completed Dec. 1935

CAPE COD CANAL
MASSACHUSETTS
RAILROAD BRIDGE
ALIGNMENT & LEVELS

IN 1 SHEET — SHEET NO. 1 — NOT TO SCALE

U.S. ENGINEER OFFICE BOSTON MASS.

SUBMITTED: — APPROVED:

APPROVAL RECOMMENDED: — DISTRICT ENGINEER

FILE NO.

FIGURE I-6

PART V-2

SUPERSTRUCTURE

PART V-2 - SUPERSTRUCTURE

The superstructure includes the lift span, the north approach span and tower, and the south approach span and tower. The findings of the in-depth examination of all structural members within these three portions of the bridge are presented in this section of the report. Recommendations for maintenance and repairs are included at the end of the findings for each span.

Access to most of the bridge structural components was gained by climbing (see Photographs II-45, 47 and 51). The floor system members of each span, the sides of the towers and the backstay cables were examined with the aid of movable scaffolding or personnel baskets placed by a rigging subcontractor (see Photographs II-46, 48, 49 and 50).

Figures 2-1, 2-2 and 2-3 show the span and tower members described in the following findings.

The superstructure members are generally in good structural condition. Significant section loss was noted in lacing bars of the truss and tower primary and secondary members. Major section loss was also noted in occasional rivets and bolts. All lacing bars with an estimated loss of cross-section over 25 to 30 percent are tabulated at the end of this Section. Rivets and bolts with 50 percent or greater loss of head or nut are listed in the recommendations for each span.

Although the bridge was last painted in 1981-82, paint deterioration is evident at many areas of underlying accumulations or "pockets" of rust, especially around connections. The corrosion residue is visible under the new paint, indicating the metalwork was not properly cleaned prior to repainting. Generally, no significant loss of metalwork section was observed on the webs, angles or cover plates of the primary or secondary members.

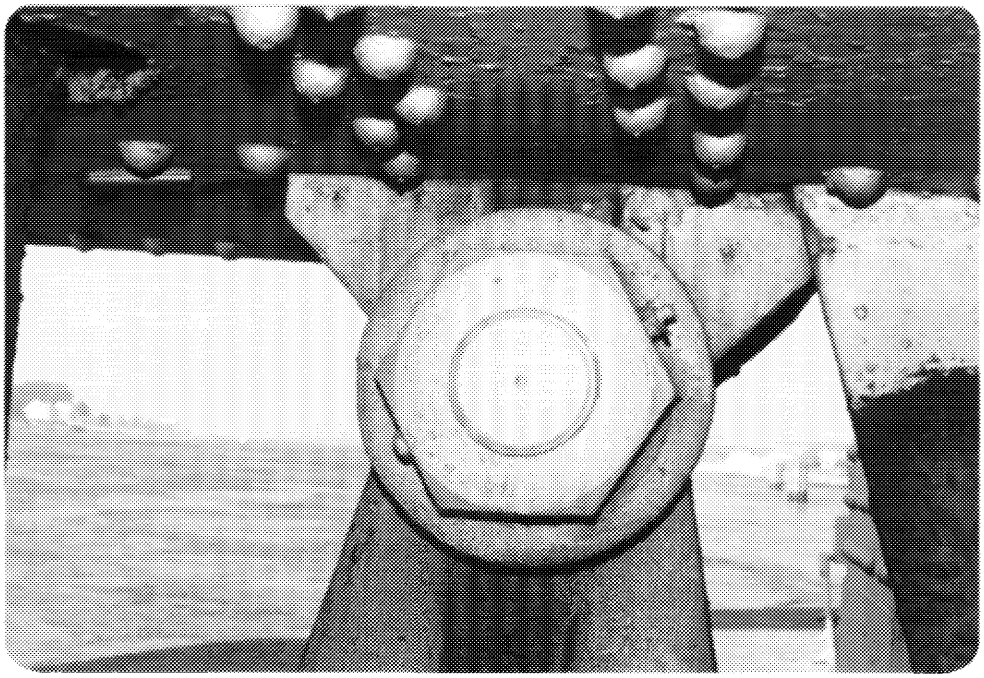
V-2-1 - LIFT SPAN

The major finding in the lift span is the significant section loss in many of the truss and sway frame lacing bars. Areas of the metalwork require a thorough cleaning and painting.

Bearings

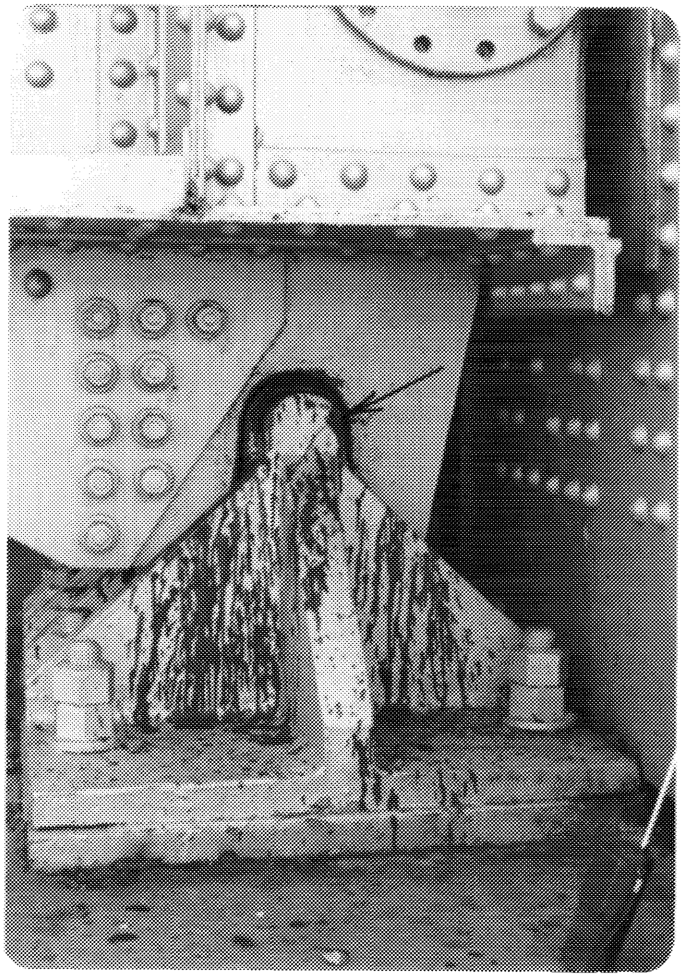
The expansion rocker bearings at the north end of the span, the fixed shoes at the south end and the centering castings at each end are functioning properly.

A small gap and rust stains, indicating minor relative movement, was observed between the expansion bearing upper shoes and the truss horizontal connection plates on the inboard end of both devices. A scraper blade can be inserted in the gap at the west bearing (see Photograph I-5). This condition may be caused by elongated connection bolts.



Photograph I-5 - Note rust stains and gap between west expansion bearing upper shoe and horizontal connection plate.

During and after seating of the lift span, contact exists on the south portion of the circular wear plates for the west fixed bearing upper and lower shoes. A 1/8 inch gap exists on the top and the north side between the wear plates of the west shoes (see Photograph I-6). Normal wear exists at the point of contact. Contact between the circular surfaces of the upper and lower shoes at the east fixed bearing is at the crown. Moisture and debris is being trapped in the pockets of the fixed bearing lower shoes (see Photograph II-56).



Photograph I-6 - Arrow indicates point of contact between shoes at west fixed bearing.

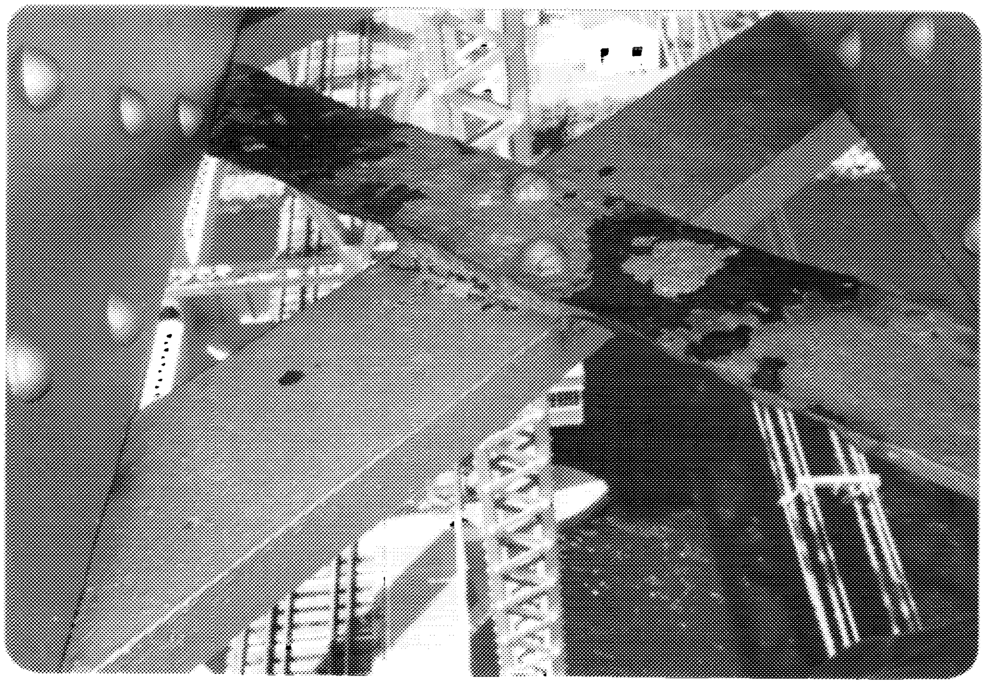
The contact surfaces of the expansion bearing and centering casting parts show evidence of minor section loss due to normal wear and corrosion. The build-up of graphite lubricant on the outer portions of the wearing surfaces not in contact is trapping moisture and causing corrosion of the underlying metalwork (see Photographs II-57 and 60).

At both ends of the lift span, the slotted vertical plates which receive the span locking mechanism when the bridge is seated, have moderate thickness section loss, especially on the lower portion (see Photograph II-59). The plates need to be thoroughly cleaned and painted.

Many of the nuts and lock nuts for the turned connection bolts of the upper shoes for the expansion and fixed bearings and both centering castings have significant section loss on the backside (see Photograph II-58).

Trusses

Corrosion is penetrating through the paint cover on the top chord cover plates and at areas along the web plates (see Photographs II-62, 63 and 77). The lacing members on the underside of top chords consist of channel and bar sections. Major section loss has occurred in the bar sections, generally between Panel Points 4 and 6 and between Panel Points 4' and 6' on both trusses (see Photographs I-7 and II-61 and 64). The channels have packed rust and section loss at their connections to the chords.



Photograph I-7 - Deteriorated lacing bar in east top chord between Panel Points 5' and 6'.

The truss verticals, diagonals and bottom chords are generally in good condition, although section loss exists on the lacing bars at some locations. Corrosion "breakouts" have developed throughout the members, but are mainly concentrated at the bottom chord joints, where pigeon wastes and other debris collects. Rivet heads are "blossoming" and show section loss in the joints as a result of the corrosion (refer to Photographs II-70 through 75).

In the longer of the two bolted stay plates at the upper end of the west truss vertical U4'-L4', the heads are missing from two connection bolts (see Photograph II-66). In addition, one bolt is missing in the shorter stay plate at the upper end of the east truss vertical U4-L4.

Table 2-I lists the lacing bars in the lift span with section loss in excess of 25 to 30 percent.

The outboard lift span counterweight ropes are contacting the edges of the top chord cover plates and upper flange angles at Panel Points U0 and U0'. The edges of the cover plates and angles at U0' have been trimmed; however, the nearest rope still is contacting the west truss (see Photograph II-67).

Top Lateral and Sway Frame Bracing

All elements of the truss bracing appear to be structurally functional.

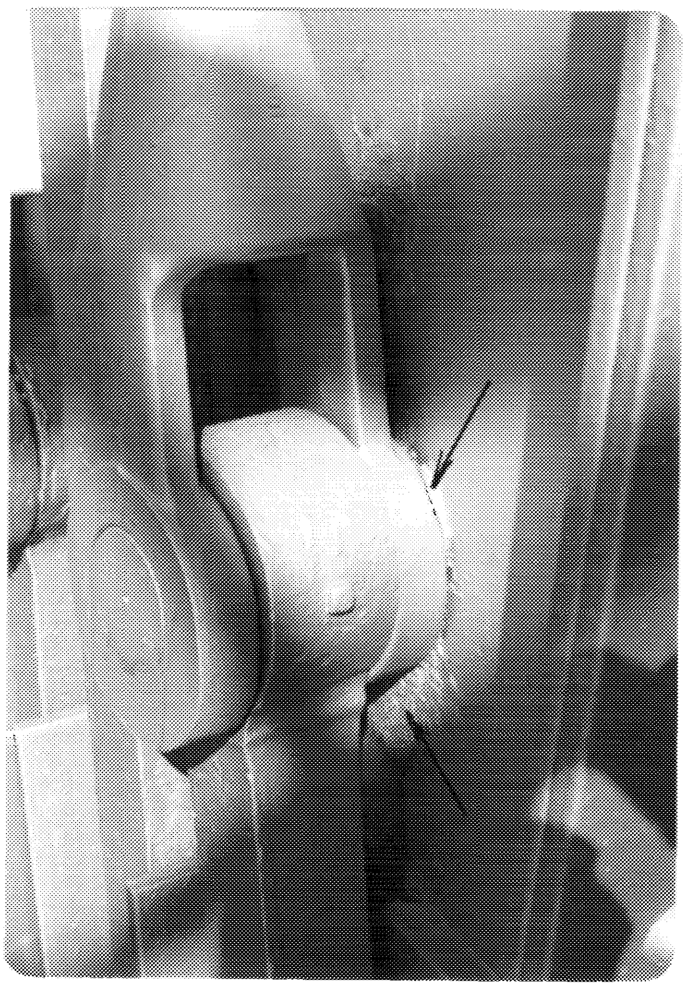
Corrosion over an extended period of time has developed pitting and general section loss on the bracing members. The existing loss on the top lateral bracing is generally confined to the lacing bars and is not considered significant. Section loss in the sway frame lacing and several angle sections is considered more serious and may become detrimental to the functioning of the members (see Photograph I-8). Packed rust and minor section loss is evident on members at the edges of connection plates.

Photograph I-8 - Section loss in sway bracing angle at Panel Point 2'.

Moisture and debris is being trapped on the end and mid-length lower stay plates of the inclined portal strut at Panel Points U0 and U0'. Corrosion, lamination and section loss is evident on the lower portions of the plates. Drain holes have been provided in the center plate; however these are partially clogged with debris. Moisture is also being trapped in the upturned angle on the tower side of each portal strut (see Photograph II-87). Drain holes should be provided in these members.

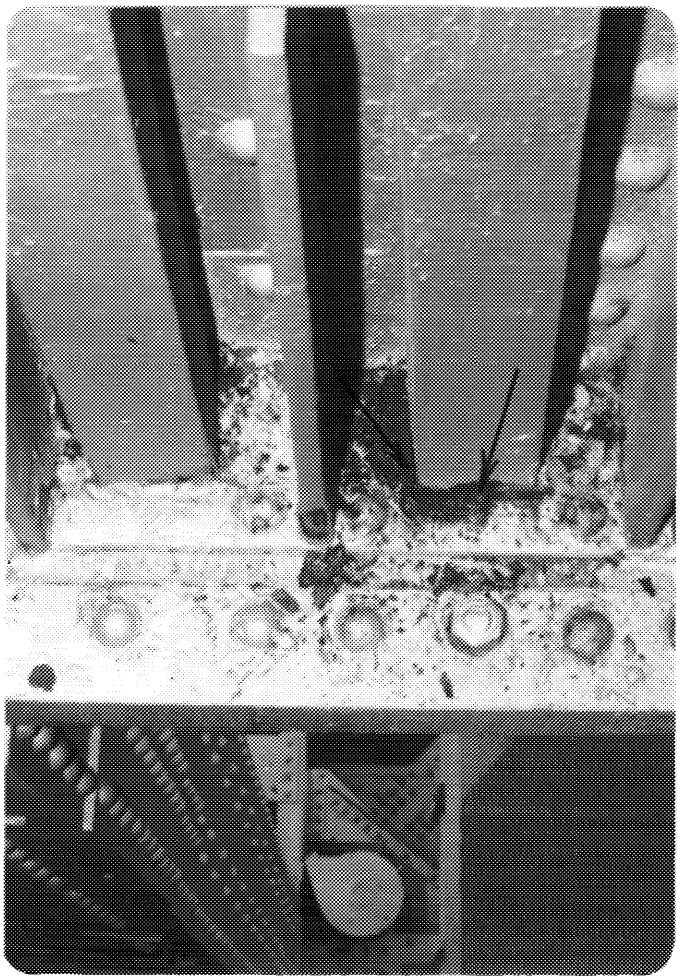
Photographs II-76 through 83 show conditions of the top laterals and sway frame bracing. Table 2-1 lists the sway frame lacing bars with a minimum loss of 25 to 30 percent. Sway frame angles in need of replacement are listed in the recommendations.

The bottom flanges of the lifting girders have a heavy build-up of paint and trapped debris, which is retaining moisture and accelerating corrosion. The girder web areas behind the counterweight rope take-up bars and sockets is not accessible for cleaning and painting. Corrosion residue and section loss, up to 1/8 inch in depth, was visible in the lifting girder webs at these locations (see Photograph I-9). Separation of paint cover was noted on other areas of the girder webs.



Photograph I-9 - Corrosion and section loss is typical in the lifting girder webs at the counter-weight rope connections.

A minor amount of section loss exists on the counterweight rope take-up bars at the lifting girder bottom flange. Moisture is being retained in the open gaps between the bar and the flange (see Photograph I-10).



Photograph I-10 - Typical corrosion and gaps between take-up bars and lifting girder bottom flange.

A 1/2 inch gap exists between the bronze bearing washers and the take-up bar anchor nut retaining plates on the underside of the lifting girders. Corrosion and packed rust has formed in the gap.

On the south side of the lifting girder at Panel Point U0, two fastener nuts for the east counterweight rope guide casting are severely deteriorated.

Photographs II-84, 85, and 86 illustrate the lifting girders.

Floor System and Lower Lateral Bracing

No major structural defects were observed in the floorbeams, stringers, stringer bracing or truss lower lateral bracing.

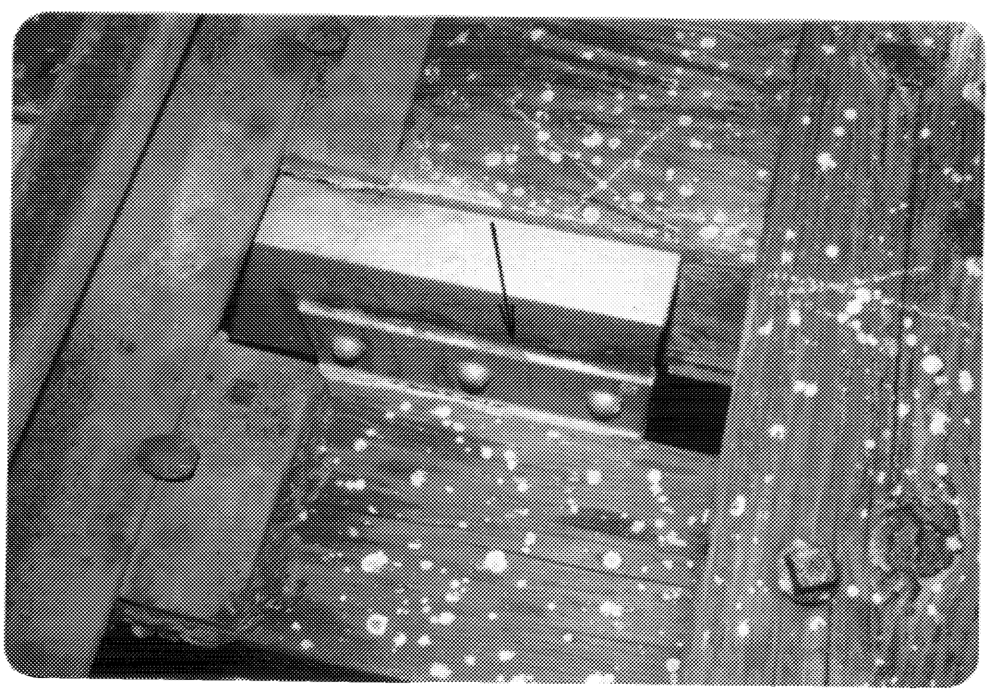
Debris accumulation, corrosion and light section loss exists on the lateral bracing system. Corrosion is most evident at the connection of the laterals to the floorbeams and stringers. Minor section loss exists on some lateral splice plates at bridge centerline and on the laterals or stringers adjacent to the shim packs at the stringer lower flanges.

Other findings include occasional deteriorated rivet heads and rusted areas on the stringers and floorbeams. The stringer top flange angles show light loss of section where the walkway support channels are connected. Photographs II-88 through 96 show the conditions noted in the floor system.

Walkways, Platforms and Ladders

The supports, gratings and railings of the walkways and platforms, and the access ladders on the span are in generally good condition.

The webs of many walkway transverse support channels are corroded with up to 1/8 inch of section loss at the top of the connection angles on the stringer top flanges (see Photograph I-11). In addition, the heads of the rivets through the channel bottom flanges at the stringers have loss of section. At each channel a timber tie abuts the open side of the member, preventing access for cleaning and painting. The open sides of the channel should be thoroughly cleaned and painted and deteriorated rivets replaced when ties are replaced. Additional rivets on the back side of the channels pass through the connection angles mentioned above to add redundancy.



Photograph I-11 - Typical area of corrosion and section loss in walkway support channels.

Several deficiencies were noted in the stair railings on each end of the span. At the bottom of the north stairs, the end cap on the west lower inclined pipe is severely deteriorated. The short section of railing support pipe at the second "T" connection from the top of truss member U0-L1 at the south end of the span is completely missing. The west upper railing pipe is disconnected at the elbow and the lower elbow is loose at the top of the south stairs.

Between Panel Points L2 and L3, the NASA equipment, previously mounted on the east truss, has been removed and newer railing sections installed. Single 1/2 inch bolts used to connect the upper portions of the newer railing sections to the original sections are loose. Corrosion and rust stains from vibration movement of railing at the connections is visible.

Section loss and pitting were noted in straps and support angles around the flashing red navigation markers mounted on the lift span bottom chords.

Photographs II-97, 98, 99 and 100 show the railing deficiencies.

A 2 x 4 inch guard timber exists between the walkway grating and end of the timber ties in each span. The timber is deteriorated at many locations and should be replaced.

Recommendations

General

1. Cleaning and painting of the span is recommended within the next five years. A thorough sandblast cleaning should be specified at areas of corrosion, lamination and packed rust on members and joints.

2. Replace the truss and sway frame lacing bars listed on Table 2-1.

Bearings

3. Remove the graphite compound from the non-contact surfaces of the bearings, centering devices and span lock assemblies. Remove all corrosion from the steel surfaces and apply paint to the surfaces not in bearing and lubricant at the contact surfaces.

4. Replace a total of 40 fasteners connecting the upper shoes of the fixed and expansion bearings to the trusses. Replace a total of 64 fasteners in the upper shoes of the truss centering castings.

5. Provide an outlet for trapped moisture in the lower shoes of the fixed castings.

Trusses

6. Trim the interior edge of the upper flange angle and cover plate at Panel Point U0, east and west trusses, and Panel Point U0', west truss.

7. Replace a missing bolt in the upper stay plate on the north side of the vertical at Panel Point U4, east truss, and two bolts in the upper stay plate on the south side of the vertical at Panel Point U4', west truss.

Top Lateral and Sway Frame Bracing

8. Replace a missing bolt in the lateral bracing connection at Panel Point U5', west truss. The fastener is missing on the north side of the strut.

9. Replace the following sway frame bracing angles:

   a) Panel Point 2 - The upper north angle on Member KF and the lower north angle on Member GC.

   b) Panel Point 8' - The lower north angle on Member KG.

   c) Panel Point 2' - The upper north angle on Member KF.

10. Remove the counterweight rope take-up bars from the bottom flange of the lifting girders during replacement of the ropes, and thoroughly sandblast clean and paint the lifting girder webs and lower flanges and the take-up bars.

11. Replace two deteriorated fasteners nuts for the east counterweight rope guide casting on the south side of the lifting girder at Panel Point U0.

12. Provide drain holes in the upturned angle on the tower side of the end portal strut at Panel Points U0 and U0'.

Floor System and Lower Lateral Bracing (Locations of Members and Joints are shown on Figure 2-4)

13. Replace deteriorated rivets in the bottom flanges of the following floorbeams:

   a) Panel Point 7 - One rivet in the north flange on the outboard side of the west stringer.

   b) Panel Point 7' - Two rivets in the north flange, one below the west stringer and one on the outboard side of the east stringer.

   c) Panel Point 3' - Four rivets in the north flange, one below each stringer and two between the stringers. One rivet in the south flange below the west stringer.

d) Panel Point 2' - One rivet in the south flange between the stringers.

14. In Panel 3'-4', replace one rivet each in the northeast and southwest stringer-lateral bracing connections.

Walkways, Platforms and Ladders (Locations of Members and Joints are shown on Figure 2-4)

15. Replace one missing rivet in the west stringer connection of walkway support channel member 29.

16. Replace the end cap for the lower railing pipe at the bottom of the north stairs. Replace the short section of pipe for the T connection and provide new fasteners for the elbow sections of the railings at the top of the south stairs.

17. Provide new fasteners with lock washers for the upper angle railing sections between Panel Points 2 and 3.

18. Replace the 2 x 4 inch guard timber between the walkway grating and the end of the ties.

V-2-2 - NORTH APPROACH SPAN AND TOWER

The truss span and tower are generally in good structural condition. There are areas on nearly all the structural members where underlying corrosion is penetrating through the paint cover.

Bearings

The Abutment D bearings consist of one set of roller bearings under each truss and one floorbeam/stringer rocker bearing at bridge centerline. On Pier C, a fixed bearing supports each stringer at the end floorbeam and rocker shoes exist at the lower end of the tower columns. All the bearings appear to be unrestricted and functioning as designed.

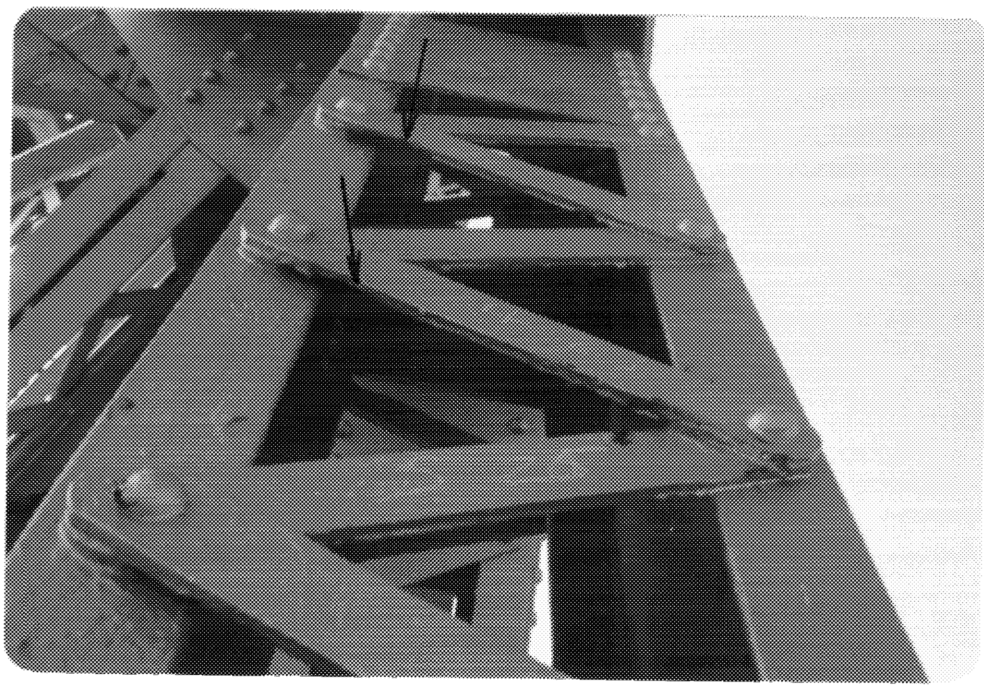
Previously developed corrosion is penetrating through the recent paint cover, as illustrated in Photographs II-105, 106 and 107. Corrosion exists on the contact surfaces of the centerline rocker bearing on Abutment D (see Photograph II-102).

The position of the abutment expansion bearing upper shoes and rockers was located with respect to marks placed on the fixed base plates of the devices in 1971. The 1984 readings are consistent with the past readings. Figure 2-5 shows the location of the reference marks on the bearing shoes and the changes in the position of the bearings as recorded during this examination.

The outboard anchor bolts for the west truss bearing at Abutment D are bent to the south; however, this condition is not causing any restriction and no adjustments are required.

Trusses

Several minor deficiencies were noted in the trusses. Lacing bars, with a minimum of 25 to 30 percent section loss exist at locations, with the majority in the verticals and diagonals (see Photograph I-12). Table 2-2, attached, is a listing of lacing bars with a minimum of 25 to 30 percent section loss.



Photograph I-12 - View of deteriorated lacing bars on west truss Member U2-G.

Corrosion is active to some degree on all members, but is most apparent at the bottom chord joints (see Photograph I-13). Pigeon waste and other debris has accumulated in the top and bottom chord joints.

Photograph I-13 - Typical corrosion in truss lower chord joints.

The extent of section loss on fasteners is generally negligible, but significant loss was noted at several locations. Ten rivets on the bottom chord lower connection plate at Panel Point 4, east truss, have approximately 50 percent section loss and should be replaced (see Photograph II-108). All fasteners with significant section loss are listed in the recommendations.

Electrical conduit support bracket angles attached to the inboard side of the east truss verticals at Panel Points U2 and U4 are severely deteriorated and will require replacement. A conduit support angle at the east end of the transverse strut at Panel Point U1 is also in need of replacement (see Photographs II-130 and 132).

Top Lateral and Sway Frame Bracing

Several deficiencies were noted in the sway bracing at Panel Points 2 and 4 and the top lateral bracing system.

The batten plate at Point E on the portal strut at Panel Point 4 has severe section loss and will require replacement. Twelve rivets on the east stay plate adjacent truss joint U4 require replacement.

The bracing members have areas where corrosion is penetrating through the paint cover. The corrosion has caused light pitting and section loss at locations generally at or adjacent to connections. Four lacing bars on the portal at Panel Point 4 require replacement due to extensive deterioration. These are listed on Table 2-2.

Floor System and Lower Lateral Bracing

The surfaces of the floorbeams, stringers, stringer bracing and lower lateral bracing show light corrosion and deteriorated paint with "pockets" of packed rust and minor section loss developing at connections.

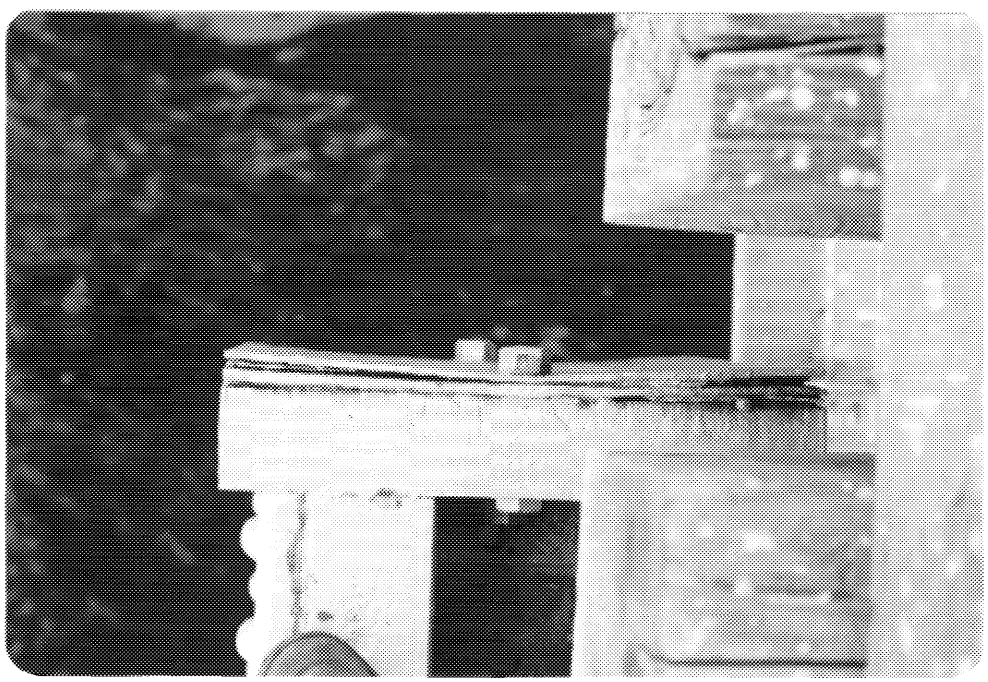
Minor section loss exists on the stringer top flange angles at locations where the walkway grating support channels are fastened. Areas of more severe corrosion exist on horizontal plates, such as the lower lateral and stringer bracing connection and splice plates (see Photographs II-122, 123 and 128).

Fastener deterioration is not significant at this time, although some rivet heads having section loss of 15 to 30 percent were noted. Rivet heads in floorbeam top flange cover plates under the walkway grating have been trimmed for clearance. Corrosion has further reduced the heads of several fasteners and replacement is warranted.

Pack rust exists between the vertical legs of some back-to-back lateral bracing angles (see Photograph II-127).

Jacking Strut

Two jacking struts are provided for placement between the lift span end floorbeam and lifting girder when the counterweight ropes are replaced. One strut is stored in the north span and one in the south span along the west stringer between Panel Points 1 and 2. The repairs recommended for the struts in the 1971 Inspection Report were completed. Drain holes were provided in the web; however, corrosion of the strut metalwork is continuing. Packed rust has formed between the shim plates on the north end, causing section loss and displacement of the plates (see Photograph I-14).

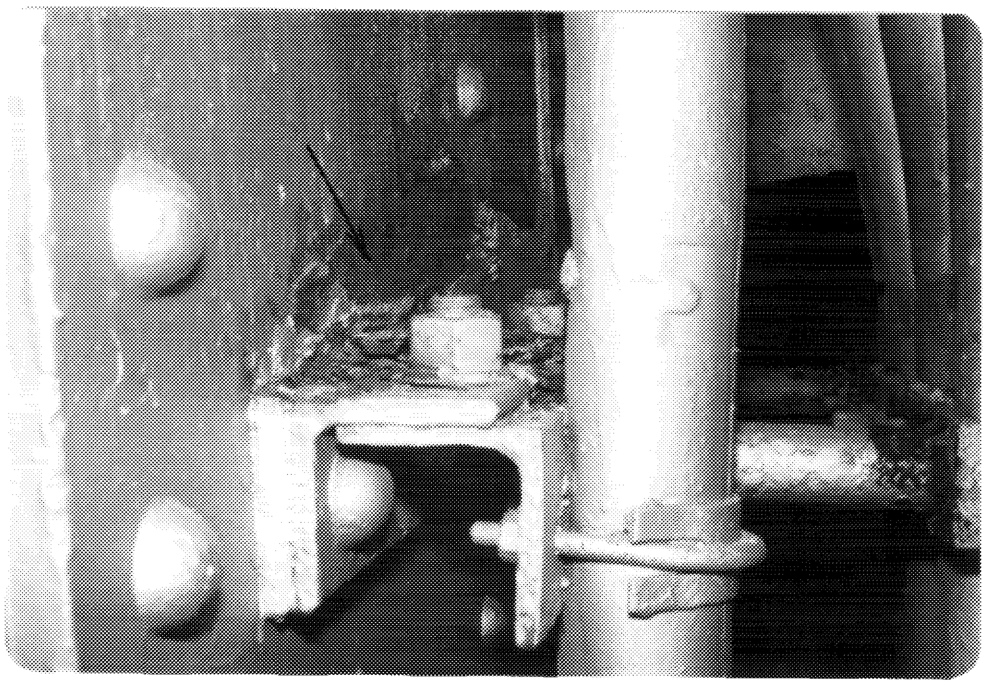


Photograph I-14 - Displaced shim plates and packed rust at lower end of north span jacking strut.

Tower Members

The towers consist primarily of four columns with diagonal and horizontal bracing. The towers support the main sheaves, counterweights, lift span and associated machinery. The structural members are generally in good functional condition. The main deficiency concerns areas of continuing corrosion due to improper cleaning prior to repainting.

Corrosion and section loss are a concern on the outboard side of the interior web plates of the rear columns directly above the electrical conduit support angles (see Photographs I-15 and II-137). The web section loss is presently 1/16 to 1/4 inch in depth along the top of the angles. The area is not easily accessible and was not thoroughly cleaned during the most recent painting contract. The support angles should be removed to aid in thoroughly cleaning and painting the web plates. Support angles not presently being utilized, should not be reattached.



Photograph I-15 - Corrosion and section loss on interior web plate at bracket near top of east rear column.

Section loss also exists on the inboard side of the web plates of the rear columns adjacent to the vertical connection angles for the center set of lacing (see Photograph I-16). The present depth of loss is 1/8 to 3/16 inches. This area will require special cleaning and painting.

Photograph I-16 - Corrosion and section loss in rear column web plate adjacent center lacing connection angle.

Excessive deterioration exists in several lacing bars of the bracing members. Those with section loss in the range of 25 to 30 percent and over are listed in Table 2-2. The front tower columns are perforated on the rear face and a horizontal diaphgram plate is located in the column, just below each opening. Extensive corrosion exists on the diaphgram plates, connection angles and rivets. Typically, the rivets are "blossoming" with an estimated 15 to 20 percent section loss and the angles and plates are generally laminated (see Photograph I-17 and II-141). Metalwork corrosion in the west front column is more advanced, with some rivet heads having more than 50 percent loss of section.

Photograph I-17 - Typical corrosion on diaphgram plates, angles and rivets. Rivets have an estimated 15-20 percent loss of section.

Overall, the paint cover is in fair condition. Many areas of established corrosion have re-appeared. Excess lubricants, dropping from the lifting ropes and sheave areas, has stained the tower members and created an oil impregnated finish. This coating should be removed prior to repainting.

The transverse tower strut at Point C1 consists of double lacing bars between four angles. A hole exists in the vertical leg of the south lower angle near the west end.

The transverse tower strut at Point C0 consists of a horizontal web plate attached between two transverse angles on the north side and the bottom flange of the transverse sheave Girder G5 on the south side. Moisture and debris is being retained on the upper surface of the strut, causing metalwork lamination and section loss on rivet heads (see Photographs II-148 and 149). The upper surfaces of the strut need a thorough sandblast cleaning, prior to repainting and drain holes should be installed in the web at intervals.

The heads of several rivets fastening the counterweight guide angles to the support brackets and vertical gusset plates along the front columns have significant section loss from corrosion (see Photographs II-150 and 151). Figure 2-6 indicates the fasteners in need of replacement. Minor section loss was noted in the guide angles adjacent to several of the rivets. At locations along the guide angles, the ends of the connection rivets are worn flat from contact with the counterweight guide shoes. The remaining section of the fastener heads is satisfactory for the connections.

Balance blocks for the main counterweight are being stored on the horizontal struts between the front columns of the towers. The concrete blocks rest on timber strips which retain moisture. This arrangement is causing corrosion of the structural members. The blocks should be temporarily removed when the next painting of the span is undertaken.

Top of Tower

The structural members at the top of the tower consist of ten sheave girders and associated bracing. The main sheave girders are supported by two transverse sheave girders on the front and rear sides of the tower. Four fascia girders and a machinery house enclose these members. A decorative spire is situated atop the machinery house.

An accumulation of paint, debris, corrosion and pigeon waste exists on the upper surfaces of the sheave girder bottom flanges and adjacent horizontal connection plates. This has caused light section loss (see Photographs II-156 and 161).

On the outboard side of the sheave Girders G1-E and G1-W, an 18" x 3/8" horizontal plate is attached between the girder bottom flange angle and a fascia plate that extends downward to tower strut C0-C1. Corrosion and packed rust exist along the edges of the plates adjacent to the flange angles and the plates are warped near mid-length with section loss. The nuts on replacement high-strength bolts fastening the 3/8 inch plate are starting to corrode and laminate (see Photograph II-162). Corrosion has caused severe section loss in the outstanding legs of the vertical stiffening angles of the girders over the lower 4 inches. Many have near 100 percent loss of the legs (see Photograph II-157). Excess accumulations of pigeon debris exist on the ends of the horizontal plates in the tower legs, which has also caused minor to moderate loss of section on the vertical interior angles of the columns.

The portions of the sheave girders adjacent to the sheaves are relatively inaccessible and have not been cleaned and painted recently (see Photograph II-159). This condition has not resulted in any significant section loss. Heavy accumulations of grease and debris exist on the bottom flanges in this area.

Small gratings have been placed between the sheave girder bottom flanges adjacent to the counterweight ropes. The gratings are intended as access for examining and lubricating the ropes. The connection fasteners and the ends of the gratings show section loss. Several gratings are severely deteriorated at their ends (see Photographs II-166 and 167).

The interior sides of the counterweight hangers and adjacent support metalwork and the pin collars have not been recently painted. Corrosion has caused a maximum of 1/8 inch depth of pitting in the hangers and adjacent support plates at the pin collars. The heads of fasteners for the pin collars are severely deteriorated (see Photograph I-18). The pin collars should be removed and the metalwork sandblast cleaned and painted.

Photograph I-18 - Typical corrosion and minor section loss on pin collars and fasteners and interior surfaces of counterweight hanger plates and support metalwork.

At the entrance to the sheave room from the balcony, gratings rest on the exterior sheave girder top flange plates. Debris and corrosion residue needs to be thoroughly cleaned from these areas to prevent significant section loss on rivet heads.

The interior of the machinery room is orderly and appears to be well maintained. In the sheave room, no structural defects were apparent in the exposed steel framework of the walls and roof. Paint separated from the walls of the sheave room and metalwork above the machinery room was noted. Pigeons roost above the ceiling of the machinery room and the waste accumulation is very heavy. In addition to remains of birds, old boxes, barrels and miscellaneous items have been stored in this area.

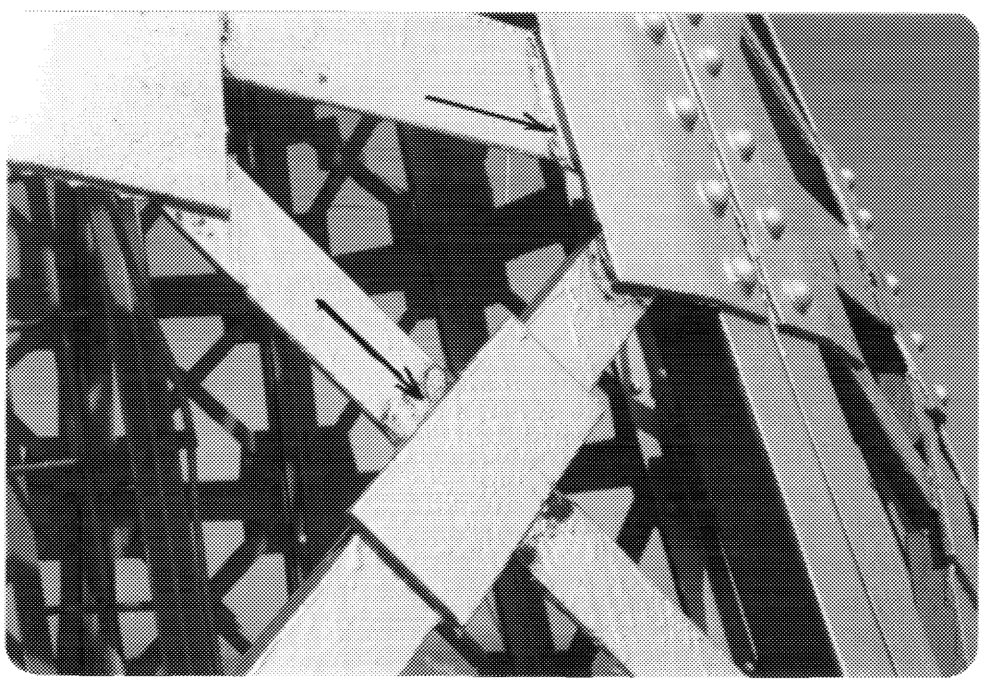
Several deteriorated fasteners were noted on the southeast and southwest corners of the sheave room enclosure. Locations of these are given in the recommendations (see Photograph II-172).

Corrosion and peeling paint exist at local areas on the exterior surfaces of the machinery house and fascia girders. On the back side of the fascia girders, packed rust and minor section loss exist along the balcony railing post members. These areas need to be sandblast cleaned.

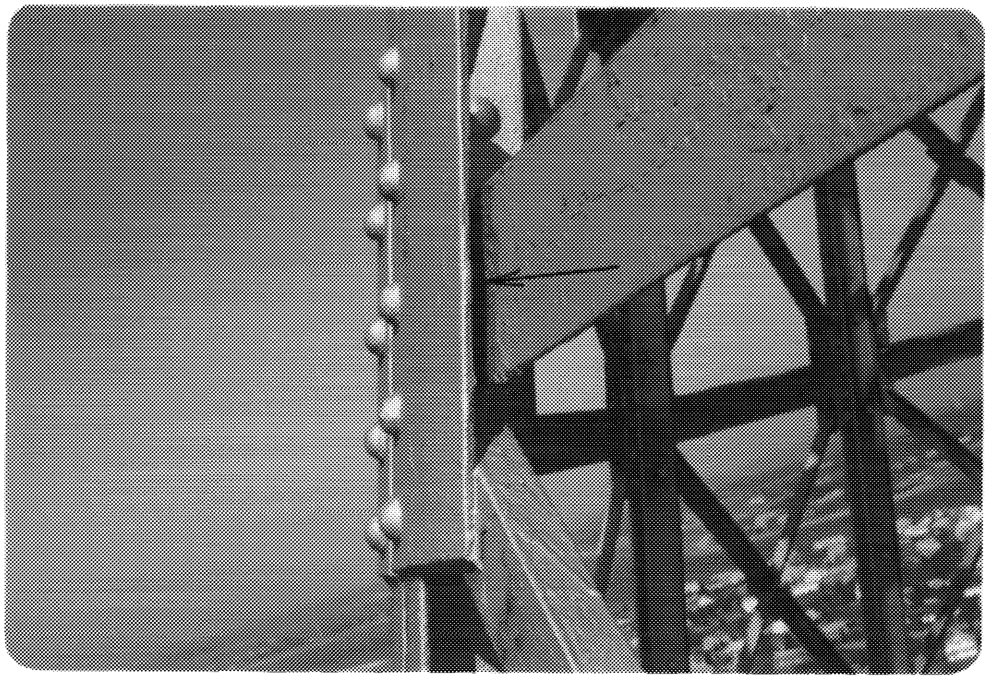
Several window panes in the enclosure are broken, but remain in the frames. The glazing compound around the panes is generally dry and cracked. The metal frame around the single window pane in the north section of the double entrance door on the west side of the enclosure is deteriorated and has holes in the lower portion (see Photograph II-176).

The finish paint coat on the upper surface of the machinery house roof has separated from the primer. The areas of the roof beneath the support enclosures for the decorative balls is corroded and void of paint cover. Rivet heads on the roof splice plates have over 50 percent section loss inside the enclosures (see Photograph II-183).

The decorative spire atop the machinery house enclosure consists of a welded lattice of angles. Packed rust and moderate section loss exist on these members adjacent to the connection plates (see Photographs I-19 and I-20). Many of the welds are broken, usually at the horizontal angle connections. A listing of broken weld locations is provided on Figure 2-7.



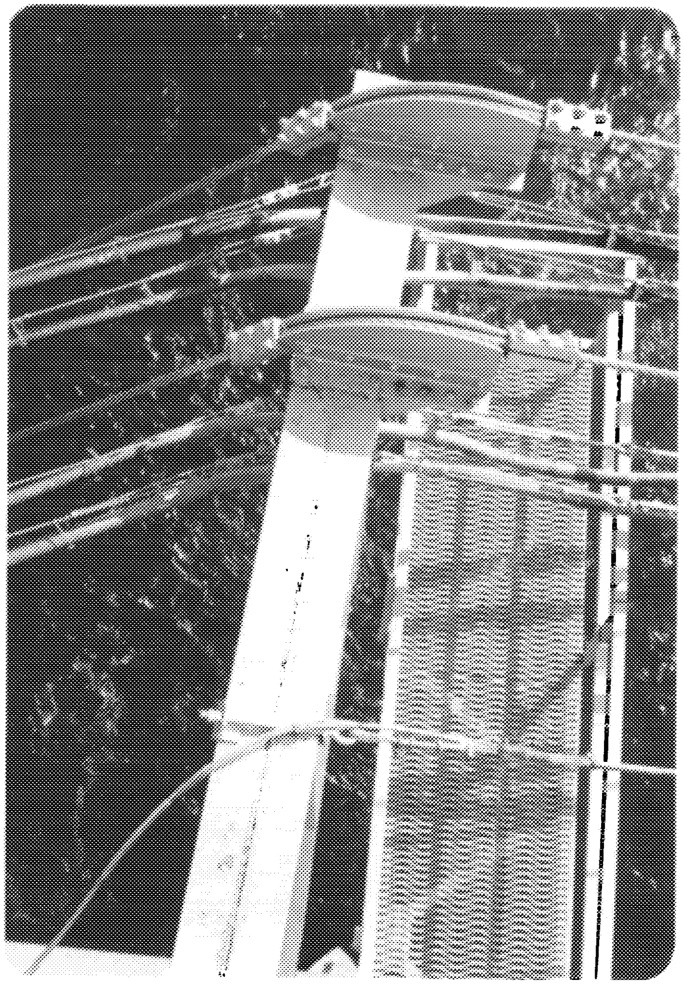
Photograph I-19 - Typical corrosion and minor section loss on north tower spire metalwork.



Photograph I-20 - Separated horizontal brace of north spire.

The area inside the decorative ball atop the spire is covered with pigeon waste.

The catenary brackets supporting the messenger cables on the east and west sides of the tower are pivoted toward the channel and the outboard ends rotated toward the channel (see Photograph I-21). The bracket rotation has apparently developed since the new messenger cables were installed in 1976-77, as no deformation was reported in the 1971 Inspection Report. Each bracket was plumbed at three locations and the amount of offset between the top and bottom flanges and the degree of rotation is tabulated on Figure 2-8. No structural cracks were observed in the bracket metalwork. The brackets should be analyzed to determine if remedial measures are required.



Photograph I-21 - Plan view of northeast catenary bracket.

Walkways, Platforms and Ladders

The following deficiencies were noted in the components of the access walkways, platforms and ladders of the north span and tower (refer to Figure 2-4 for location of walkway support members).

a) The railing post at the east end of walkway support channel 17 is severely deteriorated above the lower connection.

b) The lower and mid-height horizontal railing pipes above support channel 19 and between the span longitudinal railing and the stairs are cracked at mid-length. A similar crack exists in the lower pipe above support channel 17.

c) Two fasteners for the connection of the outboard railing post to the stairway stringer at support channel 26 are deteriorated.

d) The rungs on the lower end of the short ladder used for access to the counterweight at the top of the tower are severely deteriorated (see Photograph I-22).

Photograph I-22 -
Section loss in rungs of access ladder to counterweight.

e) The two connection bolts at the lower end of the access ladder in the south side of the sheave room, at bridge centerline, are deteriorated.

f) On the southeast corner of the machinery house, two deteriorated fasteners exist in the outboard connection of the vertical ladder to the catenary bracket platform and two deteriorated fasteners exist in the adjacent vertical support angles for the platform.

g) The upper surface of the machinery house balcony tread plates is generally rusted. Several railing posts are losing section at the level of the tread plates.

h) Similar corrosion conditions exist at the span walkway support connections to the stringers at track level, as described on the lift span.

i) The 2 x 4 inch guard timber between the walkway grating and timber ties is deteriorated.

Control House

The walls, floor and roof of the control house are in good condition. Corrosion exists on the underside of the floor plate. Deterioration of the glazing around the window panes is allowing moisture and air to penetrate the control room during severe storms.

The bottom of the south door in the entrance to the transformer room west of the control house is corroded and has holes.

Recommendations

General

1. Cleaning and painting should be accomplished on the truss and the tower span members within the next five years. A thorough sandblast cleaning is necessary at "pockets" of corrosion and lamination, prior to repainting.

2. Replace the lacing bars listed on Table 2-2 in conjunction with cleaning and painting of the structure.

Trusses

3. Replace the deteriorated electrical cable support angles on the east truss members at Panel Points 2 and 4 and in the east end of the top chord strut at Panel Point 1.

4. Replace ten rivets in the lower lateral connection plate at Panel Point L4, east truss.

Top Lateral and Sway Frame Bracing

5. Replace twelve rivets in the east stay plate of the upper portal strut at Panel Point 4. Replace the batten plate at Point E on the upper strut.

Floor System and Lower Lateral Bracing

6. Replace five rivets in the top flange of the floorbeam at Panel Point 1 and the top flange of the floorbeam at Panel Point 3 below the walkway grating.

7. Replace the missing nut on a fastener in the stringer bracing connection at Joint 7 between Panel Points 3 and 4.

8. Replace four bolts with deteriorated nuts for the rail locking mechanism at Panel Point 0.

Jacking Strut

9. Provide new shim plates for the jacking strut. Store the plates in the north tower machinery room.

Tower Members

10. Sandblast clean and repaint the horizontal diaphragm plates and angles inside the front columns. Replace rivets in the diaphragm plate connections of the west column as follows:

    a) First perforation above Joint D, replace 31 rivets.

    b) Second perforation above Joint D, replace 14 rivets.

    c) First perforation below Joint J, replace 6 rivets.

    d) Second and third perforations above Joint J, replace 6 rivets in each.

    e) Provide a bird screen at the second perforation above Joint N.

11. Remove electrical conduit support angles on the interior web plates of the rear tower columns. Sandblast clean and paint web plate metalwork and re-attach angles. Eliminate angles not presently utilized.

12. Reinforce the lower south angle of the transverse strut at Joint C1.

13. Thoroughly clean upper surface and rivet heads of the lower transverse strut metalwork at Joint C0 and provide drain holes in web plate.

14. Replace 13 deteriorated rivets fastening the counterweight guide angles to the tower metalwork.

Top of Tower

15. Thoroughly clean and paint sheave girder lower flanges, connection plates and webs adjacent to the sheaves and the upper flanges at the east and west entrances to the sheave room.

16. Remove the pin collars between counterweight hanger plates. Thoroughly sandblast clean the metalwork, repaint and reinstall the pin collars with new bolts.

17. Replace the 18" x 3/8" horizontal plate attached to the outboard lower flange of sheave girders G1-E and G1-W.

18. Replace the lower ends of the outboard stiffening angles for sheave girders G1-E and G1-W.

19. Replace the gratings and connection fasteners on the sheave girder bottom flanges adjacent to the counterweight ropes.

20. Analyze the loads on the catenary brackets atop the towers to determine if corrective measures are required.

21. Replace four fasteners at the southwest corner and six fasteners at the southeast corner of the sheave girder enclosure.

22. Remove corrosion deposits and refasten the separated bracing members in the spire lattice at locations indicated on Figure 2-7. Bracing members with excessive section loss should be replaced.

23. Replace 18 rivets in the roof splice plate below each support for the four decorative balls.

24. Replace broken machinery house window panes and the metal frame around the single pane in the west entrance door to the sheave room.

Walkways, Platforms and Ladders

25. Install a new section of railing post at the east end of support channel 17. Provide new lengths of horizontal pipe railing sections; one above channel 17 and two above channel 19. Replace two fasteners in the connection of the outboard railing post to the stairway stringer at support channel 26.

26. Replace the short ladder used for access to the main counterweight.

27. Replace two fasteners at the lower end of the access ladder on the south side of the sheave room at bridge centerline.

28. Replace two fasteners in the outboard connection of the vertical access ladder and two adjacent fasteners in the vertical support angle for the catenary platform at the southeast corner of the machinery house.

29. Replace the east and west vertical straps for the ladder cage on the north side of the machinery house.

30. Replace the 2" x 4" guard timber between the walkway grating and the ties.

Control House

31. Repair the lower end of the south entrance door to the transformer room.

V-2-3 - SOUTH APPROACH SPAN AND TOWER

The findings of the south approach span and tower are similar to those reported for the north approach span and tower. Corrosion and paint deterioration, in general, is not as extensive on the south span members.

Bearings

The truss expansion bearings and the live load rocker bearing at bridge centerline on Abutment A and the tower bearings and fixed stringer bearings at Pier B are in good structural condition. All the devices appear to be functioning as designed.

Areas of corrosion exist on the bearing metalwork and the bearing contact surfaces. The west anchor bolts of the west truss bearing on Abutment A, are bent to the north. This condition is not causing any problems, and no correction is required (see Photograph II-31).

The position of the upper shoes and rollers on the base plates for the expansion devices has not changed from the position marked during the 1971 structural inspection when adjusted for temperature variation (see Figure 2-5).

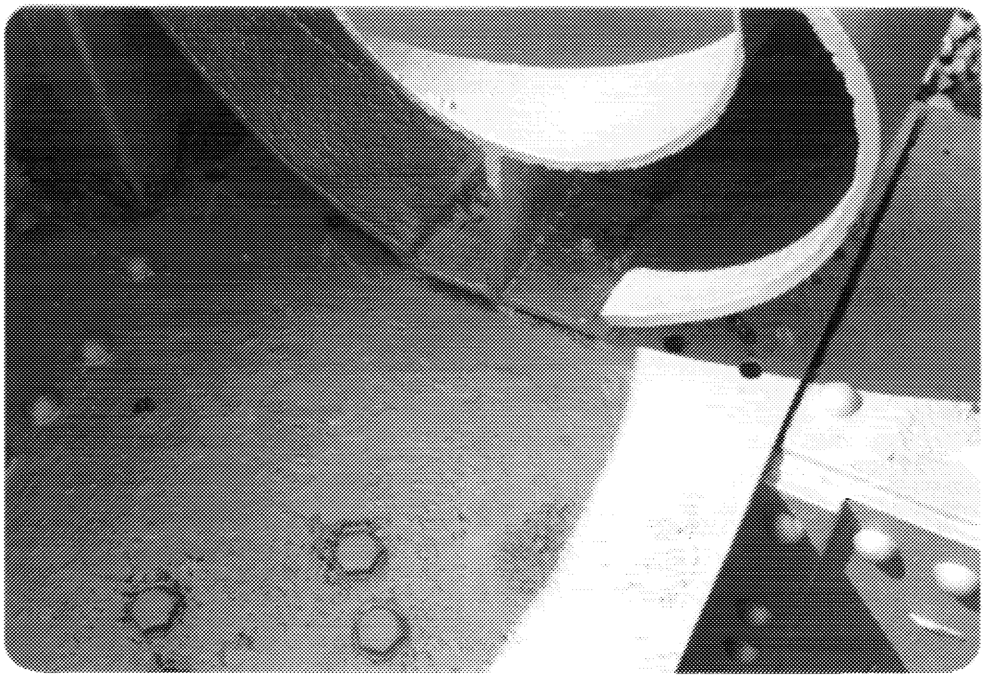
Trusses

The trusses are in good condition, with only minor deficiencies. Photographs II-112, 114, 117, and 128 illustrate the conditions which are similar to those described for the north span trusses. Table 2-2 lists deteriorated lacing bars. Fasteners with significant section loss are located in the recommendations.

Top Lateral and Sway Frame Bracing

The top lateral and sway frame bracing are in good structural condition. Areas of light corrosion have developed on the members and light to moderate deterioration has occurred on fasteners.

Five fasteners are missing in the upper lateral connection plate on the top chord at Panel Point 4, west truss (see Photograph I-23). Three fasteners are missing in the connection of a support bracket angle for the ornamental ironwork on the portal strut near bridge centerline at Panel Point 4. The west decorative ball at Panel Point 4 is dented (see Photographs II-118 and 119).



Photograph I-23 - Missing fasteners at Panel Point 4, west top truss.

Floor System and Lower Lateral Bracing

Separated and flaking paint are typical conditions found on the underside of the floor system metalwork. Corrosion "breakouts" exist throughout the members, but are usually more extensive at connections. Several fasteners are severely deteriorated and will require replacement. Other deficiencies are similar to those noted on the north approach span.

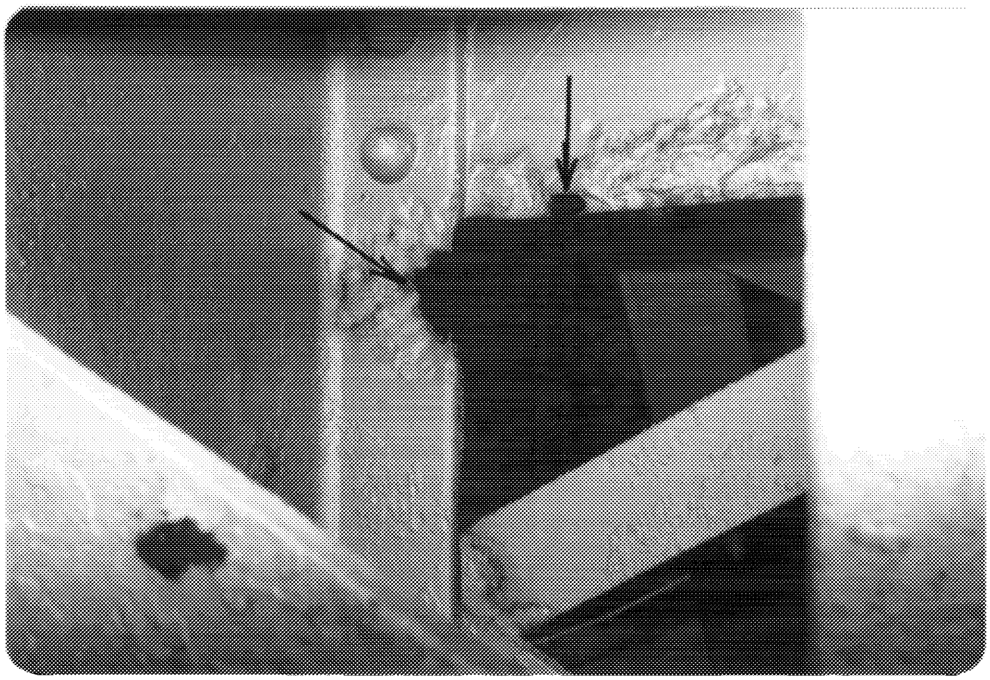
Jacking Strut

The conditions noted for the jacking strut stored on the west side of the south span at stringer level are similar to those described for the north span strut.

Tower Members

Photographs II-135, 140, 142 and 143 illustrate the general paint conditions on the tower members.

Section loss at the upper end of the east bracing member P-C1, has caused approximately 75 percent loss of section in the lower flange of the inboard channel (see Photograph I-24). The photograph also indicates section loss on the edge of the adjacent stay plate.



Photograph I-24 - Section loss on channel and stay plate of east bracing member P-C1.

A misaligned fastener hole exists in the upper end of front bracing member AO(west)-H. The hole in the upper south angle of the member will require reaming prior to installing a fastener.

The compartments inside the tower front columns were examined after removing the bird screens. Moderate to advanced corrosion and section loss exist on the horizontal diaphgram plates and the associated angles and rivets. No structural repairs are required in the compartments.

Section loss exists on the interior web plates of the rear columns, directly above the electrical conduit support angles, as described on the north tower. The present loss of metal is estimated between 1/16 and 1/4 inch in depth. Removal of the support angles is necessary for cleaning and painting the corroded areas.

Significant section loss exists in two sets of lacing bars, the adjacent stay plate and connection rivets on the east end of the laced transverse strut member at Point C1 (see Photographs II-146 and 147). Significant section loss was also noted in the bottom flange rivets of the transverse sheave girder adjacent to the deteriorated stay plate.

Deteriorated rivets exist in the connections of the east vertical counterweight guide angles to the tower members. These are shown on Figure 2-6. Several rivet heads are worn flat in the west guide angles due to contact with the counterweight guide shoes; however, no replacements are required.

Deteriorated lacing bars of the tower members with a minimum section loss of 25 to 30 percent, are listed on Table 2-2. Deficient fasteners requiring replacement are listed in the recommendations.

Top of Tower

The members at the top of the south tower are generally in the same condition as described for the north tower. The similar findings are briefly described below.

a) Bird waste, grease, paint accumulations and debris on the sheave girder flanges and horizontal connections. Similar accumulations exist in the small gratings adjacent the counterweight ropes.

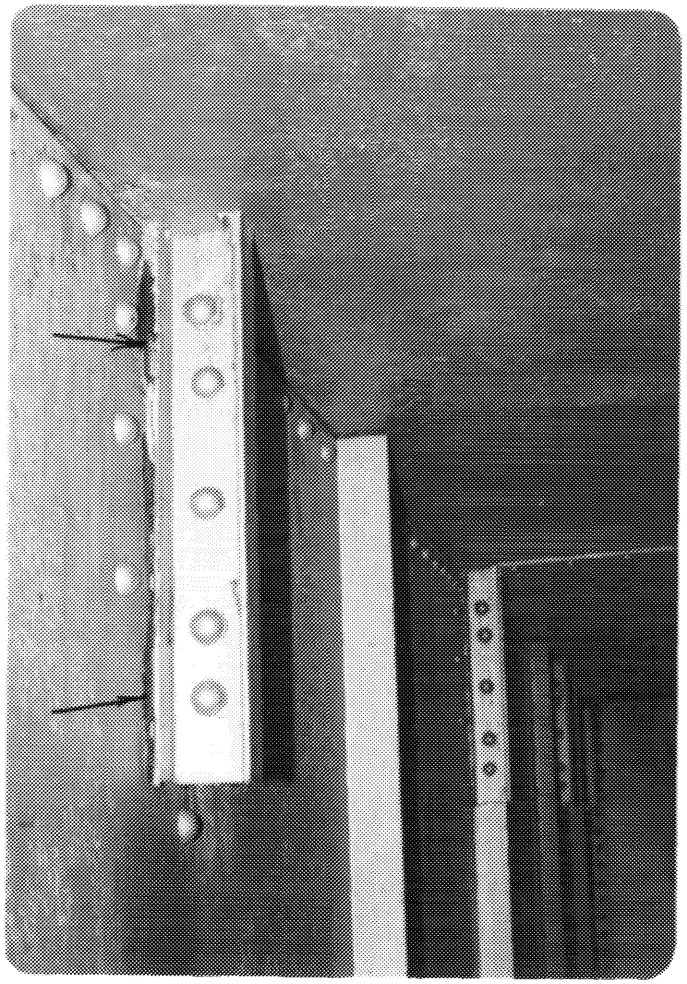
b) Corrosion and pitting on the interior surfaces of the counterweight hanger metalwork.

c) Corrosion, section loss and warping of the 18" x 3/8" horizontal plates attached to the outboard lower flanges of sheave girders G1-E and G1-W.

d) Extensive section loss in the lower ends of the outstanding legs of the web stiffener angles on the outboard side of sheave girders G1-E and G1-W (see Photograph I-25).

Photograph I-25 - Section loss in horizontal plate, fastener nuts and lower ends of stiffeners on outboard side of Girder G1-E.

e) Corrosion with separated paint on the exterior surfaces of the machinery house and fascia girders. Corrosion and moderate section loss on the backside of the fascia girders adjacent to the balcony railing posts (see Photograph I-26).



Photograph I-26 - Arrows indicate typical corrosion along railing posts at fascia girders.

f) Similar quantities of bird waste and miscellaneous debris accumulation above the machinery room ceiling (see Photographs II-168 and 169).

g) Bird waste and deteriorated rivets in the machinery house roof splice plates under the supports of the four decorative balls. The northeast decorative ball remains dented, as reported in 1971.

h) Moderate section loss in spire lattice angles adjacent to connection plates and broken welds at many connections. Locations of separated welds are listed in Figure 2-7.

i) The catenary brackets supporting the messenger cables are pivoted northward and the outboard ends are rotated in the same direction (see Figure 2-8).

Other findings specific to the top of the south tower include:

a) Fourteen fasteners are deteriorated on the north face of the sheave room enclosure (see Photograph II-170).

b) The number of broken window panes and the amount of deteriorated glazing for the machinery house windows is greater than at the north tower. In addition, lower areas of the window frames have nearly 100 percent section loss (see Photograph I-27).

Photograph I-27 - Section loss in window frames and broken panes are typical in south tower machinery house.

c) The metal frame around the single pane window in the south door on the west side of the sheave room is deteriorated with holes.

d) A short section of the sheet metal cornice on the east side of the machinery house has section loss and holes.

Walkways, Platforms and Ladders

The components of the walkways, platforms and ladders are in generally good condition. The few deficiencies are:

a) A deteriorated fastener exists at the base of the southeast railing post of the work platform on the east member M'-M. An additional fastener is also deteriorated at the north end of the exterior channel for the member (see Photograph II-188).

b) The lower rungs of the short access ladder to the main counterweight from under the sheave girders are deteriorated with section loss.

c) The hoops and vertical straps for the safety cage on the vertical ladder between the balcony area and the top of the machinery house roof have areas of section loss. The two side vertical straps have been removed (see Photographs II-190 and 191). The top rung of the ladder has severe section loss.

d) A loose connection exists at the base of the short access ladder in the decorative ball atop the spire.

e) The upper surface of the machinery house balcony tread plates is generally rusted and several railing posts are losing section at the level of the tread plates. No repairs are presently required for the railing post.

f) The 2 x 4 guard timbers between the walkway grating and ties at track level is severely deteriorated with holes at areas. The timber should be replaced to eliminate a possible safety hazard.

Recommendations

General

1. Cleaning and painting is recommended for the span and tower members, machinery house and spire within the next five years. A thorough sandblast cleaning should be specified at areas of corrosion, lamination and packed rust on members and joints.

2. Replace the lacing bars in truss and tower members listed in Table 2-2.

Trusses

No specific repairs are recommended.

Top Lateral and Sway Frame Bracing

3. Install five fasteners in the bracing west top chord connection at Panel Point 4. Install three bolts in the bracket supporting the ornamental ironwork on the portal strut at Panel Point 4.

Floor System and Lower Lateral Bracing

4. Replace one fastener in the lateral bracing splice plate in Panels 2-3 and 3-4.

5. In Panel 3-4, replace one rivet at the east connection of the first lower angle strut south of L3 between stringers.

Jacking Strut

6. Provide replacement shim plates for the north end of the jacking strut. Store the plates in the north tower machinery room.

Tower Members

7. Remove the bird screens and thoroughly clean and paint the horizontal diaphragms and connection metalwork in the tower front columns. Replace screens after cleaning and painting.

8. Remove the electrical conduit support angles attached to the interior web plates of the tower rear columns to thoroughly clean and repaint. Do not re-attach angles not presently being utilized.

9. Replace the four lacing bars and adjacent stay plate at the east end of the strut at Point C1. Replace eight rivets in the adjacent transverse sheave girder bottom flange.

10. Ream the existing hole and install a bolt at the upper end of the tower member A0(west)-H.

11. Trim the deteriorated lower flange at the upper end of the tower east bracing member P-C1. Trim the deteriorated area of the adjacent stay plate.

12. Replace two rivets in the lower connection of tower member A0(east)-M. The connectors fasten the member to the south vertical gusset plate at the joint.

13. Replace ten rivets in the lower flange of the outboard channel and four rivets in both the upper and lower inboard channel flanges of the east tower member C0-C1 lacing connections.

14. Replace eight rivets in the upper flange and two rivets in the lower flange of the inboard channel and three rivets in the upper flange of the outboard channel of the west tower member C0-C1 lacing connections.

15. Replace 10 rivets fastening the east counterweight guide angles to the tower metalwork.

Top of Tower

16. Thoroughly clean and paint areas of debris accumulation and corrosion of sheave girder webs, flanges, connection plates and small access gratings.

17. Remove the pin collars and thoroughly clean and repaint the interior surfaces of the counterweight hanger connection metalwork. Clean pin collars and provide new connection bolts.

18. Replace the 18" x 3/8" horizontal plates adjacent to the outboard lower flanges of sheave girders G1-E and G1-W.

19. Replace the lower ends of the outboard stiffening angle for sheave girders G1E and G1-W.

20. Analyze the catenary bracket supports atop the towers to determine if corrective measures are required.

21. Remove corrosion deposits and refasten the broken connections of the spire lattice angles at locations listed in Figure 2-7. Replace severely deteriorated angles as necessary.

22. Replace 18 rivets in the machinery house roof splice plates beneath each support for the decorative balls.

23. Replace broken window panes and deteriorated window frames of the machinery room and single frame in the south door of the west entrance to the sheave room.

24. Repair deteriorated cornice on east side of machinery house.

Walkways, Platforms and Ladders

25. Replace two rivets in the west stringer top flange connection of the walkway support channel 17. A vertical support for the jacking strut is attached to this member on the west end.

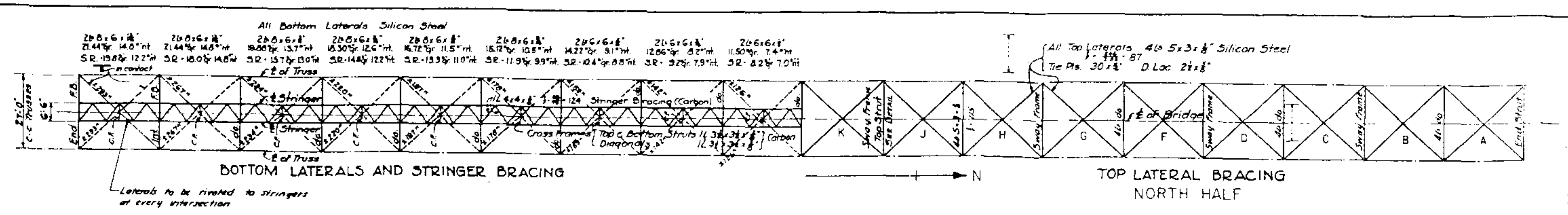
26. Replace a deteriorated fastener at the southeast corner of the access platform on east member M'-M and a fastener at the north end of the outboard channel for the member M'-M.

27. Replace the short vertical access ladder atop the tower leading to the main counterweight.

28. Replace the hoops and vertical straps on the ladder leading to the spire at the south side of the machinery house. Replace the top rung of the ladder.

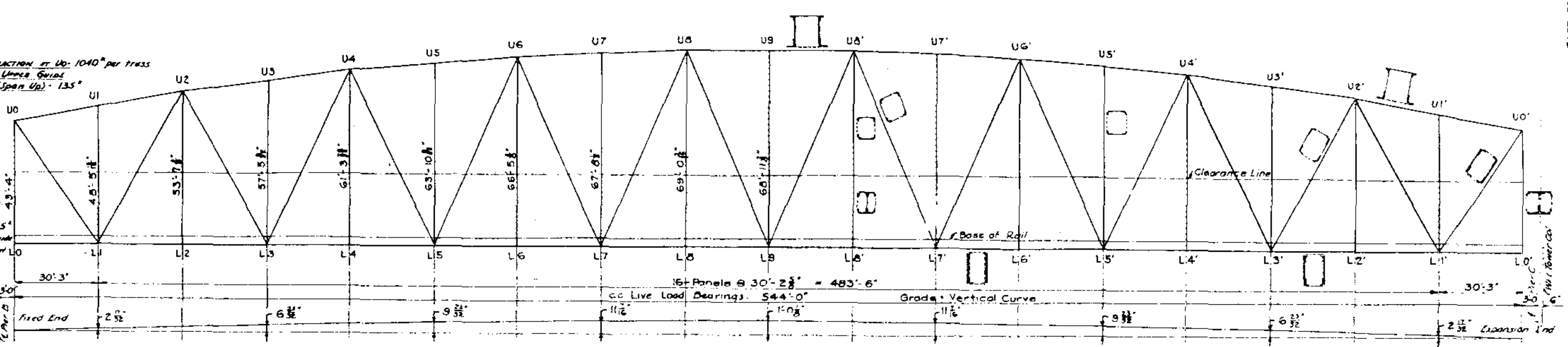
29. Refasten the loose connection at the base of the short access ladder in the decorative ball atop the spire.

30. Replace the 2 x 4 inch guard timber between the walkway grating and timber ties.

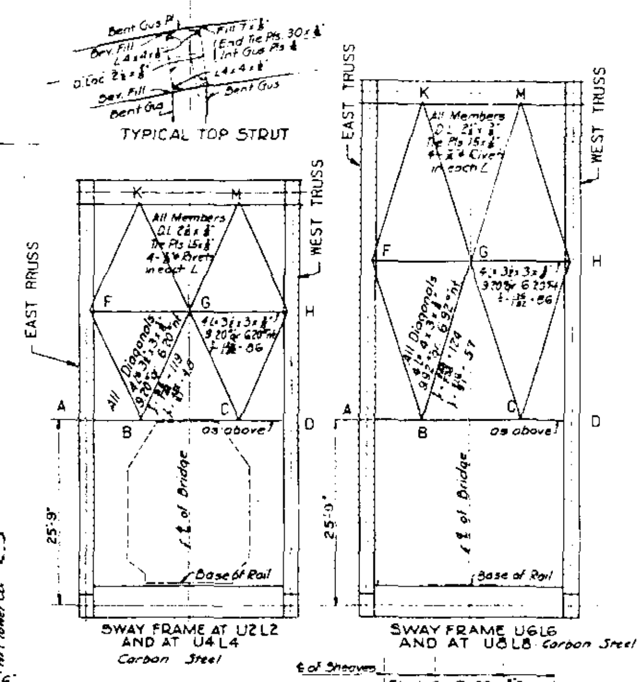


Dead Load Reaction at U0 - 1040# per truss
Reaction of Upper Guide Roller (Span Up) - 135#

Guide Roller Reactions at L0 (Span Up)
Lateral Guide 85#
Longitudinal Guide 150# per truss at this end only



OFFSET DIAGRAM FOR BOTTOM CHORD
Raise Stringers ⅛" at L2, L4, L6, L8.



Reaction at L0 - in kips per shoe (Span Down)

Dead Load (Span unbalance)	5*	
Live Load	925	
Impact	83	
Total	1013	
Lateral Wind	Horiz ±153*	Vert ±130
L.L. Lateral	±41	±4
Longit Wind	±150	±8
Traction	±150	±2

Note: With span down and no live load, the transverse centering device will resist the transverse wind load at each end. At Pier Bonly

STRINGER (Silicon)

	Shear	Moment
Dead	11500#	81000'#
Live	95100	625000
Impact	92400	608000
Total	199000	1314000

d = 2.86'
Flange Stress = 460000
S. Reqd @ 22000 = 20.9□" Net
Web @ 14000 = 14.2□" Gr.

Section: Web 38×½ = 19.5□" Gr.
∠ or ⅞ Web = 3.25 — 2.44□" Net
2∠ 8×6×⅞" = 22.96 — 19.46
26.21□" Gr. — 21.90□" Net

INTERMEDIATE FLOORBEAM (Silicon)

	Shear	Moment
Dead	27700#	270000'#
Live	130200	1335000
Impact	116000	1190000
Total	273900	2795000

d = 3.86'
Flange Stress = 726000#
S. Reqd @ 22000 = 32.9□" Net
Web @ 14000 = 19.5□" Gr.

Section:	Gr.□"	Net□"
Web Pl. 48×½ =	24.0	
Flange:		
∠ or ⅞ Web	4.00	3.00
2∠ 8×6×⅞"	19.88	15.38
1 Cov. Pl. 13×11/16"	8.94	7.56
1 Cov. Pl. 13×⅝"	8.13	6.88
	40.95	32.82

Cov. Pls. Top and Bottom
Lengths: 11/16" - 20'-0" lg., ⅝" - 15'-0" lg.

END FLOORBEAM (Silicon)

	Shear	Moment
Dead	20600#	190000'#
Live	109500	1120000
Impact	105700	1080000
Total	236000	2390000

d = 3.81'
Flange Stress = 626000#
S. Reqd @ 22000 = 28.5□" Net.
Web @ 14000 = 16.9□" Gr.

Section:	Gr.□"	Net□"
Web Pl. 48×½" =	24.0	
Flange:		
∠ or ⅞ Web	4.00	3.00
2∠ 8×6×⅞"	19.88	15.38
2 Cov. Pl. 13×½	13.00	11.00
	36.88	29.38

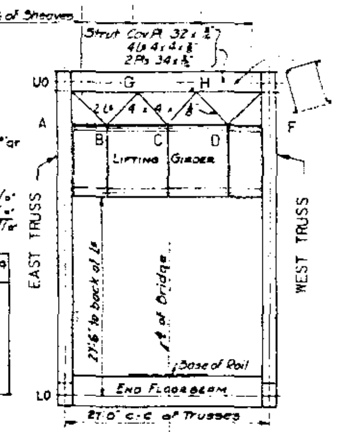
Cov. Pls. Top and Bottom
Lengths 16'-0" and Full length.

LIFTING GIRDER (Silicon)

	Vertical Moment	Vertical Shear
Rope Load	7770000'#	1276000#
Girder Load	-110000	-20000
Total	7660000	1256000

Lateral Bending in top flange due to temperature = 114000#
Web Area reqd @ 14000#/□" = 89.7□" gr.
Use 120×¾" = 90.0□" gr.
Net Section Modulus - Vertical Bending = 5140
Net Section Modulus - Horizontal Bending = 152
Max Bending in top flange Vertical Moment = 17900#/□"
Max. Bending in top flange Horizontal Moment = 7500#/□"
ft = 25400#/□"
Allowed 24000 × 1.10 = 26400#/□"

USE SECTION:	Comp. Flg. Gross Area	Comp. Flg. Net Area	Tension Flg. Gross Area	Tension Flg. Net Area
⅛ Web (120×¾")	11.25□"	11.25□"	11.25□"	11.25□"
2∠ 8×8×¾"	22.88	15.95	22.88	11.44
2 Flg. Pls. 16×¾"	24.00	24.00	24.00	17.25
Top Flg. C.P. 36×½"			18.00	7.50
Top Flg. 2∠ 4×3×½"			6.50	5.38
Bott. Flg. C.P. 26×½"	13.00	8.80		
Bott. Flg. 2∠ 4×3½×½"	7.00	7.00		
	78.13	67.10	82.63	52.82



END ELEVATION U0-L0

NOTE: All stresses in thousands of pounds (kips)
All unit stresses in kips per square inch.

Top Chords / Bottom Chords

	U0 U2	U2 U4	U4 U6	U6 U8	U8 U8'	L0 L1	L1 L3	L3 L5	L5 L7	L7 L9
Dead Load	625 C	1446 C	1868 C	2080 C	2145 C	0	1051 T	1670 T	1980 T	2120 T
Live Load						0	884 T	1324 T	1542 T	1637 T
	534 C	1163 C	1465 C	1611 C	1651 C					
Impact						0	81 T	122 T	142 T	150 T
	49 C	107 C	135 C	148 C	152 C					
D.L.+L.L.+I						0	2056 T	3116 T	3664 T	3907 T
	1235 C	2716 C	3468 C	3639 C	3948 C					
D.L.+L.L.+I.+Revs										
Wind Top C	162	331	445	511	524	103	503	787	966	1044
L.L. Lateral						46	218	341	418	452
Traction						180	145	136	127	118
Design Stress						299 T	2922 T	4380 T	5175 T	5521 T
	1235 C	2716 C	3468 C	3639 C	3948 C	299 C				
Bending Moment										
l/r	27.4	26.8	28.1	28.4	28.6	31.4				
Allowable Unit Stress						16.00 T	30 T	30 T	30 T	30 T
	13.13 C	19.67 C	19.64 C	19.63 C	19.62 C	13.09 C				
Section Area Required						53.1□" net	97.4□" net	146.0□" net	172.5□" net	184.0□" net
	94.0□" gr.	138.1□" gr.	176.6□" gr.	195.6□" gr.	201.2□" gr.	64.9□" gr.				
Section Used	1 C.P. 37×⅝" 2∠ 4×4×⅝" 2∠ 8×8×¾" 2 Pls. 34×⅝"	1 C.P. 37×1" 2∠ 4×4×½" 2∠ 8×8×1" 2 Pls. 34×13/16"	1 C.P. 38×1" 2∠ 4×4×⅝" 2∠ 8×8×1" 2 Pls. 34×¾" 2 Pls. 34×¾"	1 C.P. 39×1" 2∠ 4×4×⅝" 2∠ 8×8×1" 2 Pls. 34×¾" 2 Pls. 34×¾"	1 C.P. 39×1" 2∠ 4×4×⅝" 2∠ 8×8×1" 4 Pls. 34×¾" 2 Pls. 34×¾"	4∠ 8×4×⅝" 2 Pls. 34×⅝"	4∠ 8×4×⅝" 4 Pls. 34×⅝"	4∠ 8×6×½" 4 Pls. 34×½" 2 Pls. 34×½"	4∠ 8×6×⅝" 4 Pls. 34×⅝" 2 Pls. 34×½" 2 Pls. 18×½"	4∠ 8×6×¾" 4 Pls. 34×⅝" 2 Pls. 34×½" 2 Pls. 18×½"
Area of Section Gross	121.38□"	138.25□"	178.36□"	197.22□"	202.31□"	63.75□"	116.50□"	171.50□"	201.74□"	214.38□"
Net						53.06□"	99.62□"	147.87□"	174.17□"	184.56□"
Section Modulus										
Material	Carbon	Silicon	Silicon	Silicon	Silicon	Carbon	Silicon	Silicon	Silicon	Silicon

Diagonals

	U0 L1 L.L.	U0 L1 212% L.L.	L1 U2 L.L.	L1 U2 212% L.L.	U2 L3 L.L.	U2 L3 212% L.L.	L3 U4 L.L.	L3 U4 212% L.L.	U4 L5 L.L.	U4 L5 212% L.L.	L5 U6 L.L.	L5 U6 212% L.L.
Dead Load	1079 T	1079 T	685 C	685 C	662 T	662 T	515 C	515 C	412 T	412 T	276 C	276 C
Live Load	918 T	1946 T	16 T	34 T	610 T	1293 T	82 T	174 T	452 T	958 T	151 T	320 T
			772 C	1637 C	37 C	78 C	519 C	1100 C	103 C	218 C	380 C	806 C
Impact	84 T	178 T	15 T	32 T	70 T	148 T	61 T	129 T	68 T	144 T	79 T	167 T
			80 C	170 C	32 C	68 C	69 C	146 C	70 C	148 C	66 C	140 C
D.L.+L.L.+I	2081 T	3203 T			1342 T	2105 T			932 T	1514 T		211 T
			1737 C	2692 C			1103 C	1761 C			722 C	1222 C
D.L.+L.L.+I.+Revs												
Wind												
L.L. Lateral												
Traction												
Design Stress	2081 T	3203 T			1342 T	2103 T			952 T	1514 T		211 T
			1737 C	2692 C			1103 C	1769 C			722 C	1222 C
Bending Moment												
l/r			67.0	67.0			77.5	77.5			98.2	98.2
Allowable Unit Stress	24 T	36 T			24 T	36 T			24 T	36 T		36 T
			17.94 C	26.91 C			17.24 C	25.86 C			15.83 C	23.75 C
Section Area Required	86.7□" net	89.1□" net			55.9□" net	58.4□" net			38.8□" net	42.1□" net		8.9□" net
			96.8□" gr.	100.8□" gr.			64.0□" gr.	68.1□" gr.			46.6□" gr.	81.8□" gr.
Section Used	4∠ 8×6×⅝" 2 Pls. 32×¾" 2 Pls. 32×⅝"		4∠ 8×6×½" 2 Pls. 32×⅝"		4∠ 8×4×⅝" 2 Pls. 30×½"		4∠ 8×6×½" 2 Pls. 30×⅝"		4∠ 4×4×½" 2 Pls. 28×⅝"		4∠ 4×4×½" 2 Pls. 26×⅝"	
Area of Section Gross	106.24□"		99.76□"		70.12□"		68.25□"		53.50□"		82.47□"	
Net	90.50□"				58.91□"				47.61□"		41.22□"	
Section Modulus												
Material	Silicon		Silicon		Silicon		Silicon		Silicon		Silicon	

Diagonals (continued) / Verticals / Posts

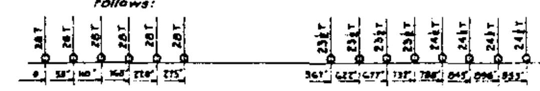
	U6 L7 L.L.	U6 L7 212% L.L.	L7 U8 L.L.	L7 U8 212% L.L.	U8 L9 L.L.	U8 L9 212% L.L.	U0 L0: U0 M0	U0 L0: M0 L0	Hangers L.L.	Hangers 212% L.L.	Posts
Dead Load	225 T	225 T	94 C	94 C	67 T	67 T	910 C		60 T	60 T	35 C
Live Load	384 T	751 T	216 T	458 T	281 T	596 T			130 T	276 T	
	167 C	354 C	296 C	628 C	226 C	479 C	844 C	844 C			0
Impact	70 T	148 T	80 T	170 T	75 T	159 T			116 T	246 T	
	74 C	157 C	68 C	144 C	81 C	172 C	78 C	78 C			0
D.L.+L.L.+I	680 T	1125 T	202 T	534 T	423 T	822 T			306 T	582 T	
	18 C	285 C	436 C	864 C	240 C	584 C	1892 C	922 C			35 C
D.L.+L.L.+I.+Revs	658 T		303 T		543 T						
	23 C		559 C		360 C						
Wind								124			
L.L. Lateral											
Traction											
Design Stress	658 T	1125 T	303 T	534 T	543 T	822 T			306 T	582 T	
	23 C	285 C	559 C	866 C	360 C	584 C	1892 C	1046 C			
Bending Moment							11700 [illegible]	[illegible]	3900 [illegible]	6600 [illegible]	
l/r	96.4	96.4	98.2	98.2	100.7	100.7	68.8	68.8			88 min. 114 max.
Allowable Unit Stress	24 T	36 T	16 T	24 T	16 T	24 T			24 T	36 T	
	15.71 C	23.58 C	11.18 C	16.77 C	11.08 C	16.62 C	22.27 C	22.27 C			
Section Area Required	27.4□" net	31.2□" net	15.0□" net	22.5□" net	33.9□" net	34.2□" net			26.7□" net	38.8□" net	
	1.6□" gr.	12.1□" gr.	30.1□" gr.	51.7□" gr.	32.8□" gr.	35.2□" gr.	147.0□" gr.	147.9□" gr.			
Section Used	4∠ 4×4×½" 2 Pls. 26×⅝"		4∠ 4×4×⅝" 2 Pls. 26×⅝"		4∠ 4×4×½" 2 Pls. 26×½"		4∠ 8×8×¾" Web Pl. 22×¾" 4∠ 4×4×½" 4 Pls. 28×⅝"		Above Sway Frame 4∠ 4×4×½" 2 Pls. 19½×½" Below Sway Frame add: 4∠ 5×4×½" Pl. 23×½"		4∠ 4×4×½" 2 Pls. 19½×½"
Area of Section Gross	40.69□"		52.47□"		43.94□"		147.02□"		52.49□"	30.94□"	26.07□"
Net	32.25□"		41.22□"		34.94□"				59.39□"	25.06□"	
Section Modulus											
Material	Silicon		Carbon		Carbon		Silicon		Silicon		Carbon

Material - As noted
Rivets - ⅞" in Stringers, Stringer Bracing, Floorbeams (except end connections to trusses) and Lateral System (except Bottom Laterals)
All others 1⅛"

SPECIFICATIONS: For entire Bridge.

General: American Railway Engineering Association Specifications for Steel Railway Bridges 1931 and for Movable Railway Bridges 1922, except as noted.

Loading: Cooper E60 and 14" Railway Artillery as follows:



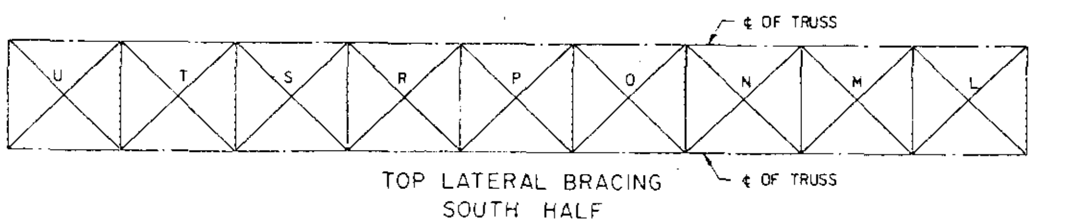
Design of Web Members: Web members designed for Live Load increased in accordance with paragraph 43 of the A.R.E.A. Specifications.

Design of Laterals:
Bottom Laterals - Silicon Steel.
f_t = 18000#/□" except End Panel = 24000#/□"
$f_c = 20000 - .46(\frac{l}{r})^2$
Bottom Laterals to be connected for net area @ 24000#/□" to provide for participation stresses
All other Laterals - Carbon Steel
f_t = 16000#/□"
$f_c = 13300 - .22(\frac{l}{r})^2$

Unit Stresses: Pounds per square inch.

	D+L+I Carbon	D+L+I Silicon		D+L+I Carbon	D+L+I Silicon
Floor System f_t		22000	Trusses f_t	16000	24000
f_c		[illegible]	f_c	[illegible]	[illegible]
Shear		14000	Shear		14000

Above unit stresses are increased 25% when Wind + L.L. Lat. + Traction exceed 25% of the total D+L+I stresses and are included in design



Recommended by [signature]
Approved by [signature]
[signature]

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Consulting Engineers
142 Maiden Lane New York, N.Y.

WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
OFFICE OF DISTRICT ENGINEER BOSTON MASS.

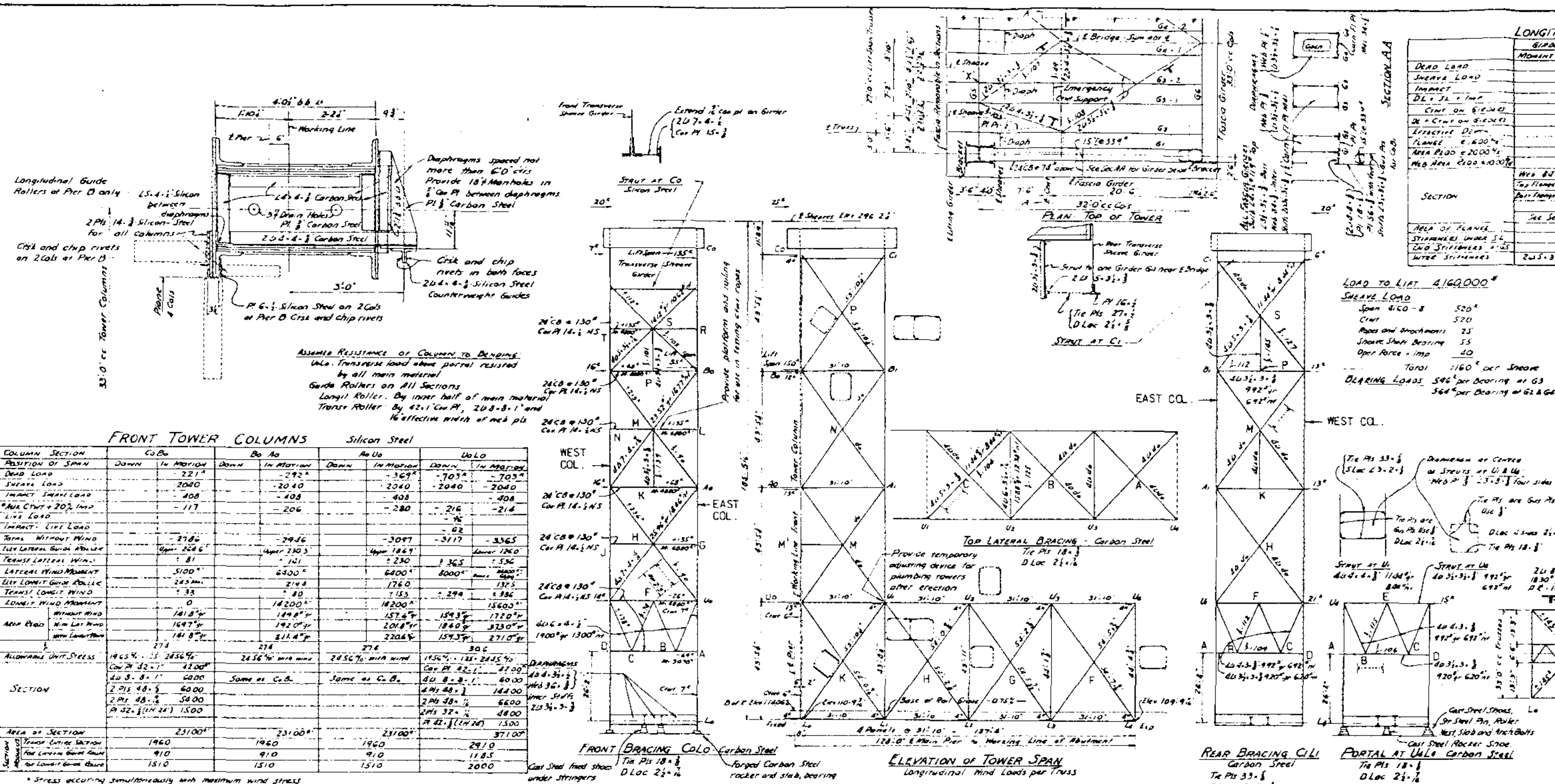
VERTICAL LIFT RAILWAY BRIDGE
OVER CAPE COD CANAL
AT BUZZARDS BAY MASSACHUSETTS

LIFT SPAN
STRESS SHEET

APPROVED [signature] LT. COL. CORPS OF ENGINEERS

MAR. 21, 1934

FIGURE 2-1



STRINGERS - Silicon Steel

	Shear	Moment
Dead Load	11800#	94000'#
Live Load	98600	683000
Impact	95400	660000
Total	205800#	1437000'#

d - 28.53" Flange Stress - 504,000#
A Reqd @ 22000#/" - 22.9" nt
Web @ 14000#/" - 14.7" gr
SECTION Web 39 x 1/2 - 19.50" gr
1/8 of Web - 3.25" gr 2.44" nt
2 L 8 x 6 x 7/8 - 24.50 20.75
27.75" gr 23.19" nt

STRINGER BRACKETS AT L4 - Carbon Steel

Moment 215000'# Shear 77000#
Use Web 39 x 3/8, 2 L 6 x 6 x 1/2 per flange
d - 32.5" S - 66000# Area of Strap Pl Reqd @ 16000#/" - 4.1" nt
Use Pl. 13 x 7/16 - 5.69" gr 4.81" nt top and bottom

INTERMEDIATE FLOORBEAMS - Silicon Steel

	Shear	Moment
Dead Load	29900#	362000'#
Live Load	136500	1809000
Impact	120100	1592000
Total	286500#	3763000'#

d - 39.0"
Flange Stress - 965000#
A Reqd @ 22000#/" - 43.8" nt
Web @ 14000#/" - 20.5" gr

SECTION	Gross	Net
Web Pl 47 x 9/16	26.44"	
Flanges:		
1/8 of Web	4.41"	3.31"
2 L 8 x 6 x 7/8	19.88	15.38
3 Cov Pls 13 x 3/4	29.25	24.75
	53.54"	43.44"

Cov Pls top and bottom
Lengths 26'0"; 21'0"; 15'6"

END FLOORBEAM AT L4 - Silicon Steel

	Shear	Moment
Dead Load	15700#	43000'#
Live Load	106000	268000
Impact	102000	258000
Total	223700#	569000'#

d - 28.6"
Flange Stress - 199000#
A Reqd @ 22000#/" - 9.1" nt
Web @ 14000#/" - 16.0" gr

SECTION	Gross	Net
Web Pl 39 x 9/16	21.94"	
Flanges:		
1/8 of Web	3.66"	2.74"
2 L 8 x 6 x 1/2	19.88	15.38
	23.54"	18"

Max End Reaction at Truss - 7800#
Max Reaction at center shoe 447400#
Stiffs over center shoe: 8 L 5 x 3 1/2 x 5/8
No intermediate Stiffs reqd

For Jacking Span at Abutment (3'6" Truss to Jack)
Moment 280000 x 3.5 - 980000'# Shear. End Reaction at Truss 280000#
d - 28.6" Flange Stress - 345000# Web Area Reqd @ 17000#/" - 16.5" gr
A Reqd @ 30000#/" - 11.5" nt Stiffs over jacks 4 L 5 x 3 1/2 x 5/8

* U4L4 and L3L4 - Maximum area reqd with LL + Imp increased 112%. See General Notes.
S - 1550# f - 18.24#/" ft - 24.00#/" A Reqd: 30.2" gr 27.9" nt

REACTIONS - IN KIPS PER SHOE

	Truss at L0 Span Up	Truss at L0 Span Down	Truss at L4 Span Up	Truss at L4 Span Down	FL Beam Shoe at L4	Transverse Shoes at L4
Dead Load	-2994	-2994	-207	-207	-32	-20
Aux Cwt	-131	-134	+71	+47		
DL Impact	-451	-37	-15	—	—	—
Aux Cwt Impact	-24					
Live Load	—	-189	—	-197	-212	-118
LL Impact	—	-123	—	-130	-204	-113
Total	-3590	-3467	-201	-547	-448	-251
Lat Wind Vert	±1362	±471	±65	±69	±3	±2
Lat Wind Horiz	±196	±86	±30	±40	±6	±3
LL Lateral Vert	—	±2	—	±2	—	±2
LL Lateral Horiz	—	±10	—	±10	—	±3
Long Wind Vert	±232	±88	±232	±88	—	±1
Long Wind Horiz	±265	±115	—	—	—	±3
Traction Vert	—	±4	—	±4	—	±5
Traction Horiz	—	±88	—	—	—	±32

Net Uplift at Pier A - Wind @ 50#/' +205#/shoe
Horiz Reaction at L4 from Aux Cwt: Span Up 50#/shoe, Span Down 35#/shoe

GENERAL NOTES:

Specifications and Loading same as for Lift Span. See Sheet 5.

Truss members are designed to provide for a 112% increase in Live Load (same as that for Lift Span) at an increase in unit stress of not more than 50% when wind is not included. This loading does not govern the design of any member except U4L4 & L3L4 as noted above.

Grillages set in Piers B & C to be furnished but not placed under this contract.

Shoes and lengths and size of Anchor bolts at Pier A shall withstand an uplift of 205#/shoe.

ALLOWABLE UNIT STRESSES

in pounds per square inch

		Carbon	Silicon
For DL + LL + Imp			
Floorsystem	f_t	—	22000#/"
	f_c	—	$22000 - 66.7(\frac{l}{r})^2$
	Shear	—	14000
Lateral System: Bott Laterals	f_t	12000#/" *	—
	f_c	$13300 - .22(\frac{l}{r})^2$	—
All other parts	f_t	16000	—
	f_c	$13300 - .22(\frac{l}{r})^2$	—
Trusses	f_t	16000	24000
	f_c	$13300 - .22(\frac{l}{r})^2$	$20000 - .46(\frac{l}{r})^2$
Front Tower Cols	f_c		$20000 - .46(\frac{l}{r})^2$
For DL + Wind			
Trusses	f_t	17600#/"	26400#/"
	f_c	$1.10[13300 - .22(\frac{l}{r})^2]$	$1.10[20000 - .46(\frac{l}{r})^2]$
Front Tower Cols	f_c	—	$1.25[20000 - .46(\frac{l}{r})^2]$
For DL + LL + Imp + Wind + LL Lat + Traction			
Trusses	f_t	20000#/"	30000#/"
	f_c	$1.25[13300 - .22(\frac{l}{r})^2]$	$1.25[20000 - .46(\frac{l}{r})^2]$
Front Tower Cols	f_c	—	$1.25[20000 - .46(\frac{l}{r})^2]$

* Bottom Laterals to be connected for net area @ 16000#/" to provide for participation stresses

MATERIAL - As noted

RIVETS - 1" for Front Tower Columns, Transv Sheave Girders G5, and for end connections of intermediate floorbeams to trusses. All others 7/8"

WIND PRESSURE - 30#/' except 50#/' for anchoring south tower span at Pier A. Maximum wind stress is Lateral Wind, Longitudinal Wind, or .7(Lat + Longit Wind)

WAR DEPARTMENT
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF DISTRICT ENGINEER BOSTON, MASS.

VERTICAL LIFT RAILWAY BRIDGE

OVER CAPE COD CANAL
AT BUZZARDS BAY, MASSACHUSETTS

TOWER STRESS SHEET

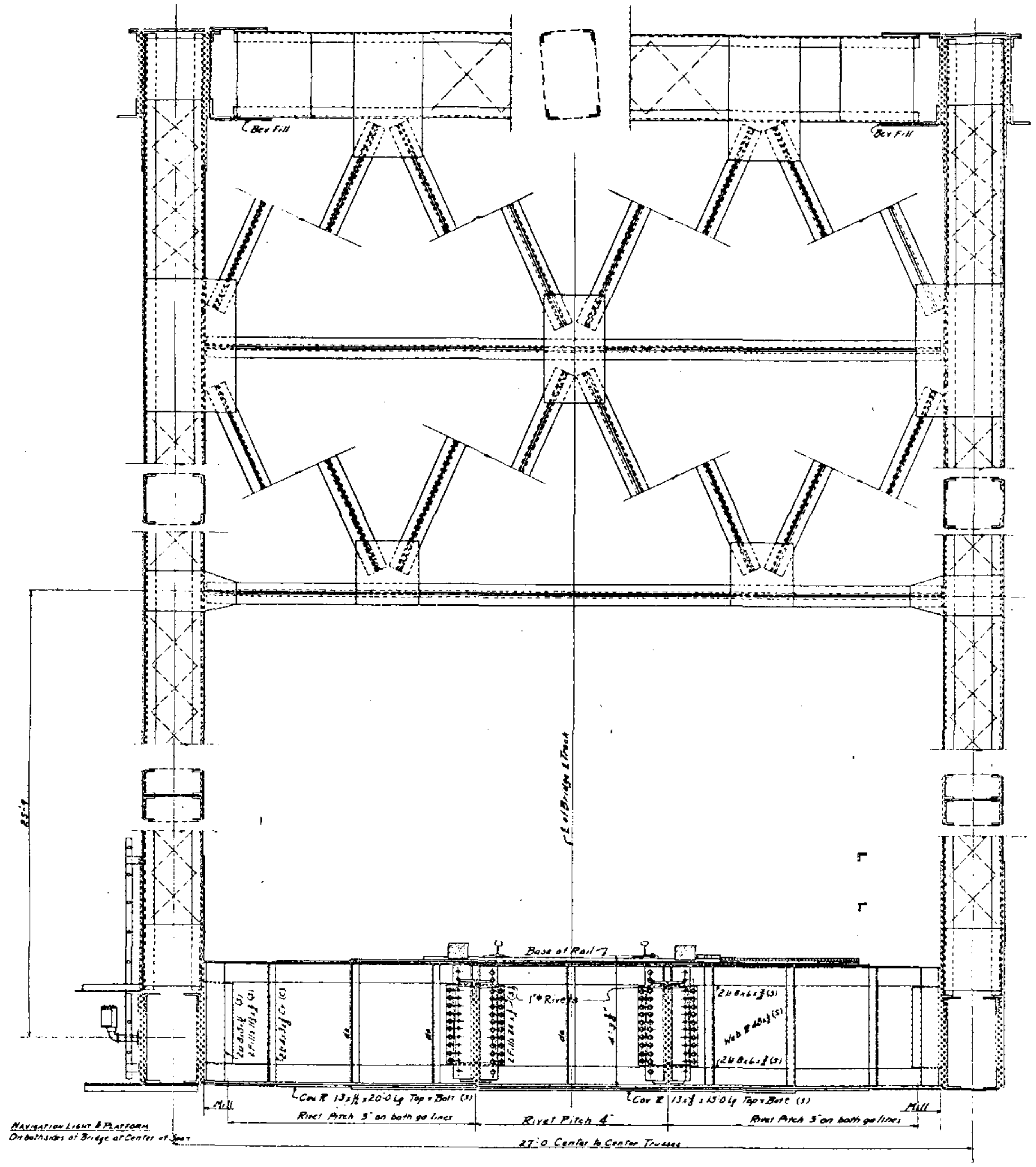
RECOMMENDED: E. L. Macdonald
APPROVED: [illegible]

PARSONS, KLAPP, BRINCKERHOFF & DOUGLAS
CONSULTING ENGINEERS
142 MAIDEN LANE NEW YORK, N.Y.

APPROVED [illegible] LT. COL. CORPS OF ENGINEERS

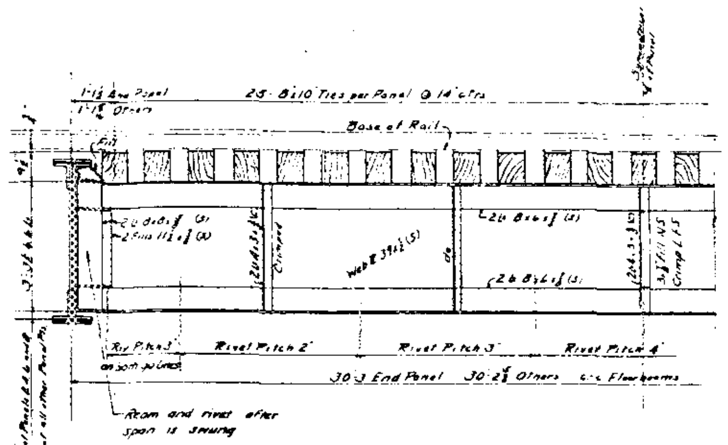
MAR. 21, 1934

FIGURE 2-2



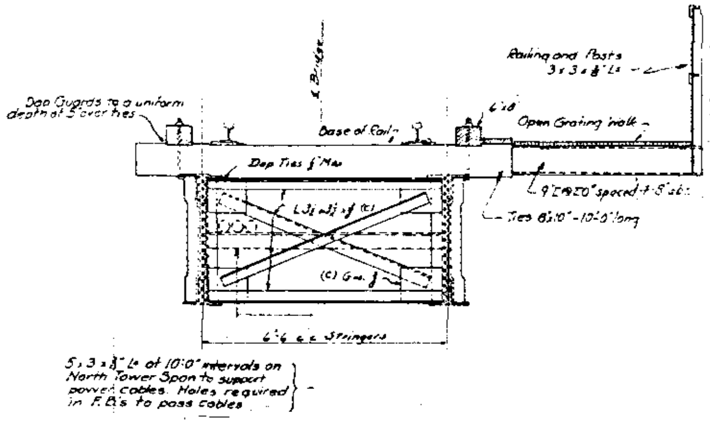
SWAY FRAME AND INTERMEDIATE FLOORBEAM

Rivets in Floor Beams ⅞"⌀ except 1"⌀ for end connection to truss and for stringer connection as shown.



STRINGER

⅞"⌀ Rivets



SECTION AT ℄ PANEL

⅞"⌀ Rivets

WAR DEPARTMENT
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF DISTRICT ENGINEER, BOSTON, MASS.

VERTICAL LIFT RAILWAY BRIDGE
OVER CAPE COD CANAL
AT BUZZARDS BAY, MASSACHUSETTS

CROSS SECTION OF LIFT SPAN

Scale ½" = 1'-0"

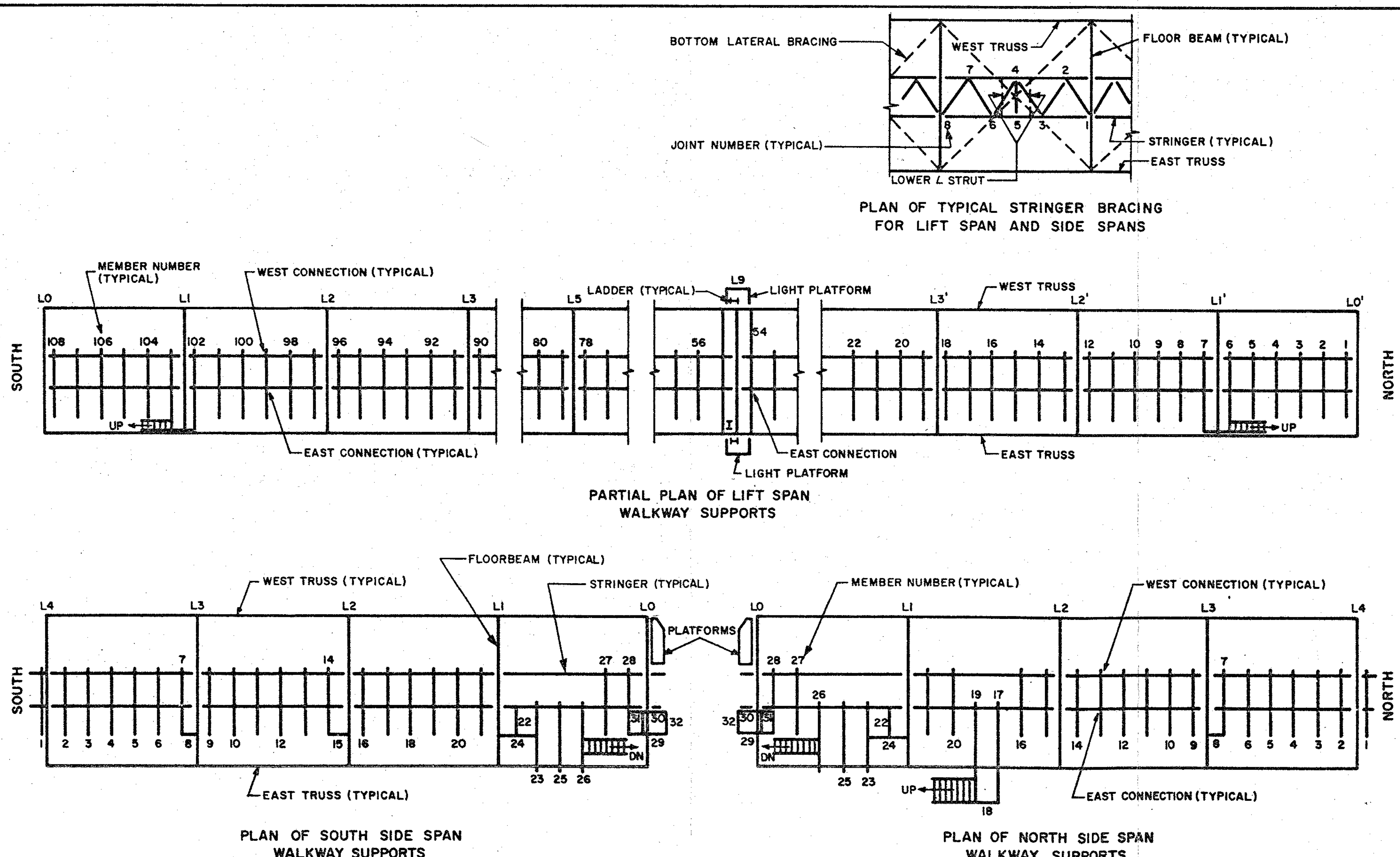
RECOMMENDED BY E. E. Macdonald
APPROVED BY [signature]
[signature]

PARSONS, KLAPP, BRINCKERHOFF & DOUGLAS
CONSULTING ENGINEERS
142 MAIDEN LANE, NEW YORK, N.Y.

APPROVED [signature] LT. COL. CORPS OF ENGINEERS

MAR. 21, 1934

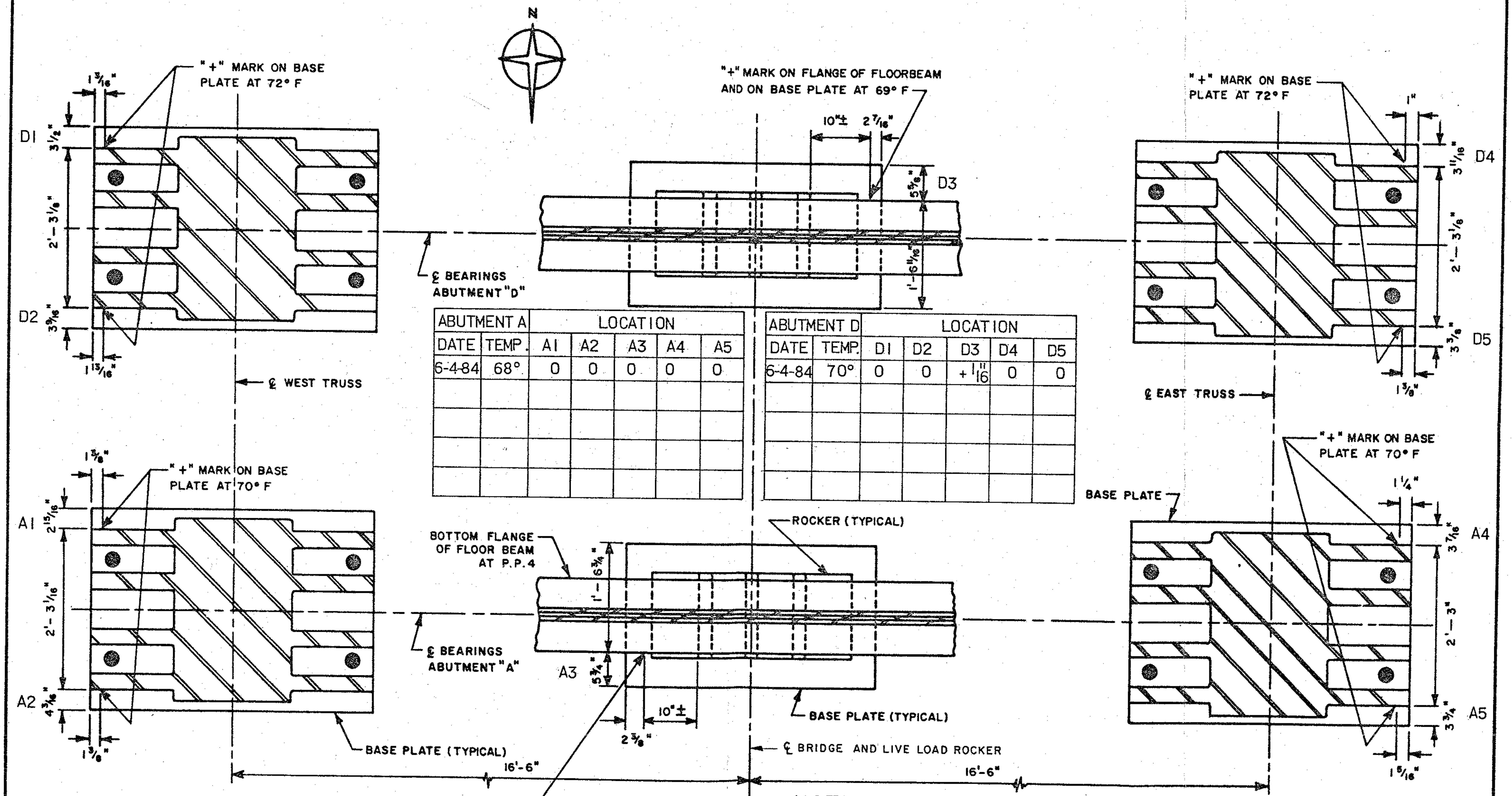
FIGURE 2-3



VERTICAL LIFT RAILWAY BRIDGE
OVER CAPE COD CANAL
AT BUZZARDS BAY, MASSACHUSETTS

STRINGER BRACING AND WALKWAY SUPPORTS
KEY PLAN

FIGURE 2-4



ABUTMENT A		LOCATION				
DATE	TEMP.	A1	A2	A3	A4	A5
6-4-84	68°	0	0	0	0	0

ABUTMENT D		LOCATION				
DATE	TEMP.	D1	D2	D3	D4	D5
6-4-84	70°	0	0	+ 1/16"	0	0

NOTES:

READINGS OBTAINED BY USING PLUMB BOB TO MEASURE OFFSET FROM ORIGINAL PUNCHMARK.

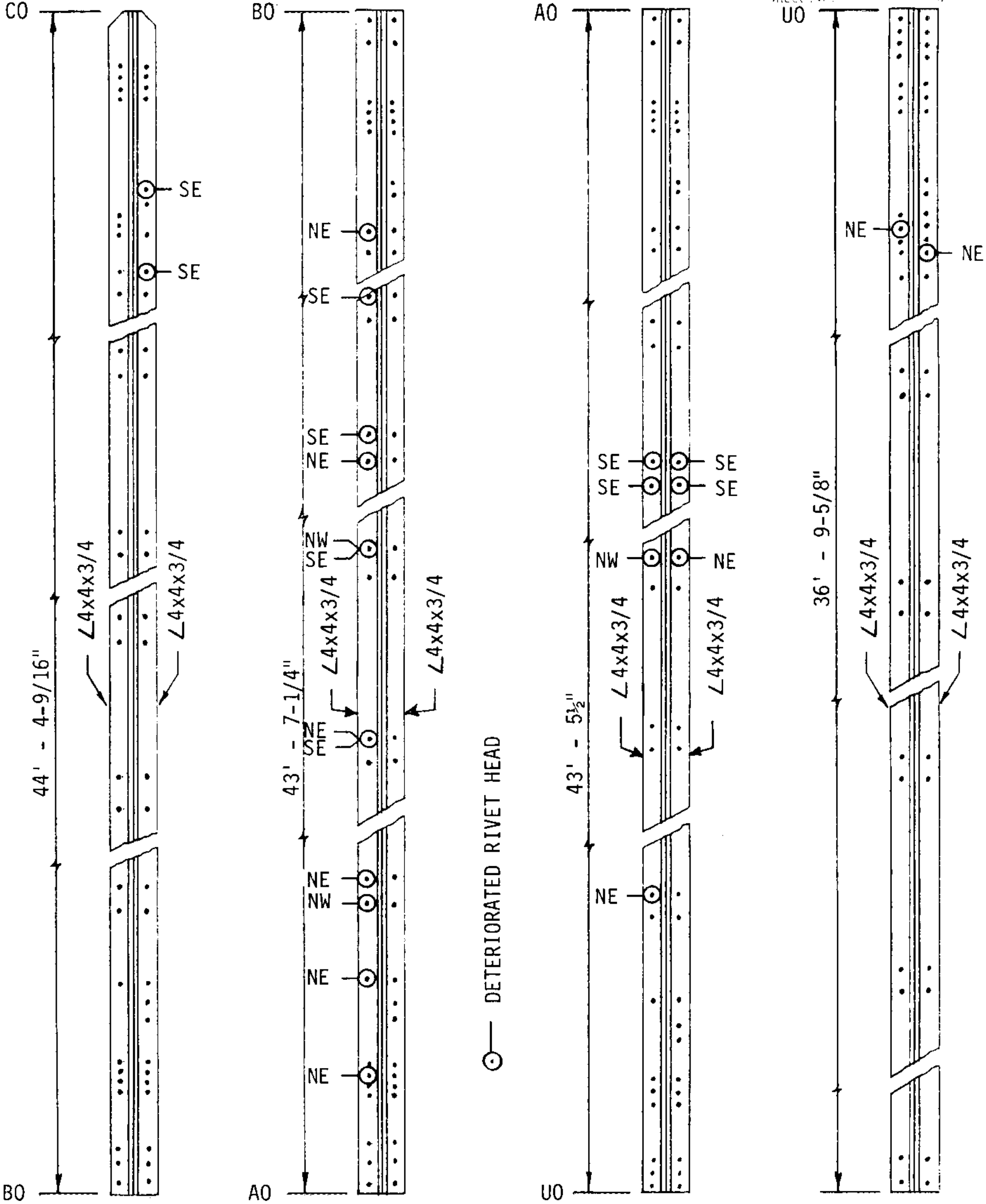
"+" DENOTES EXPANSION

"-" DENOTES CONTRACTION

VERTICAL LIFT RAILWAY BRIDGE
OVER CAPE COD CANAL
AT BUZZARDS BAY, MASSACHUSETTS

NORTH AND SOUTH ABUTMENT BEARINGS

FIGURE 2-5



COUNTERWEIGHT GUIDES

LEGEND: NE - NORTH TOWER, EAST GUIDE   SE - SOUTH TOWER, EAST GUIDE
NW - NORTH TOWER, WEST GUIDE   SW - SOUTH TOWER, WEST GUIDE

NOTES:
- LOCATION OF GUIDE SECTION IS REFERENCED TO TOWER JOINTS SHOWN ON FIG. 2-2
- NORTH AND SOUTH ANGLES ARE DESIGNATED AS IF FACING EACH GUIDE AS SHOWN.

FIGURE 2-6

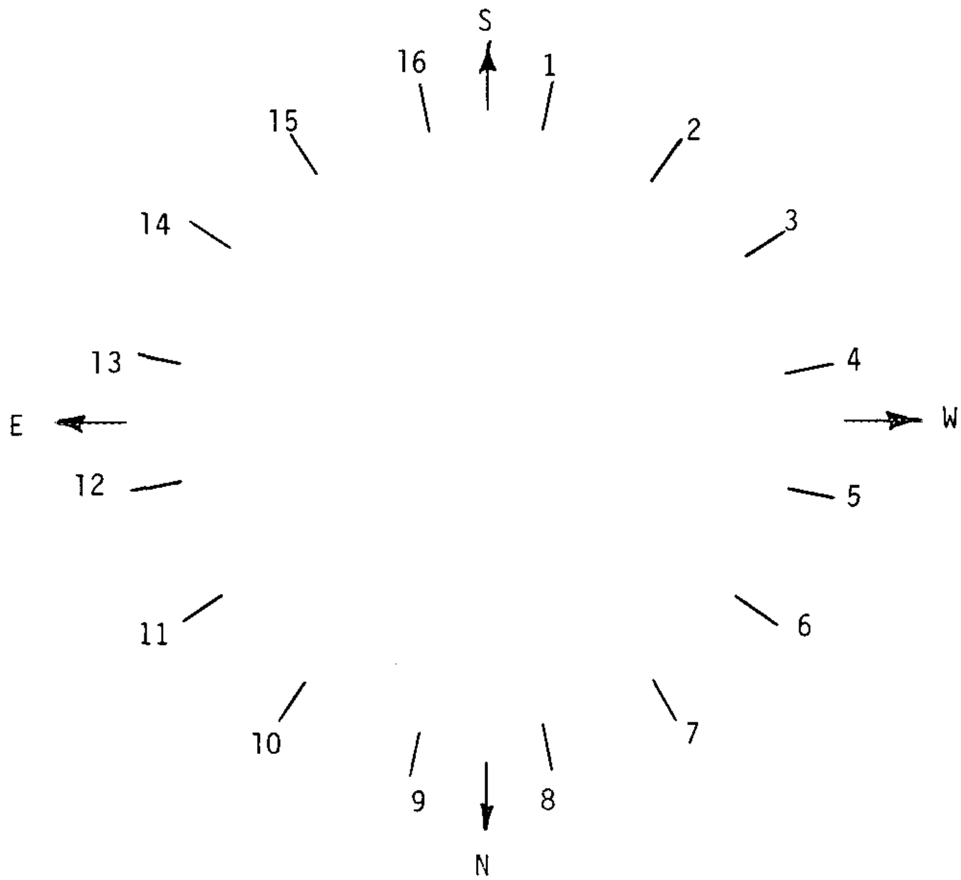
MODJESKI & MASTERS ENGINEERS

Project: VERTICAL LIFT RAILWAY BRIDGE

Subject: SPIRE LATTICE BROKEN WELDS

Made by MFB Date 6/29/84

Checked by KMK Date 7/11/84



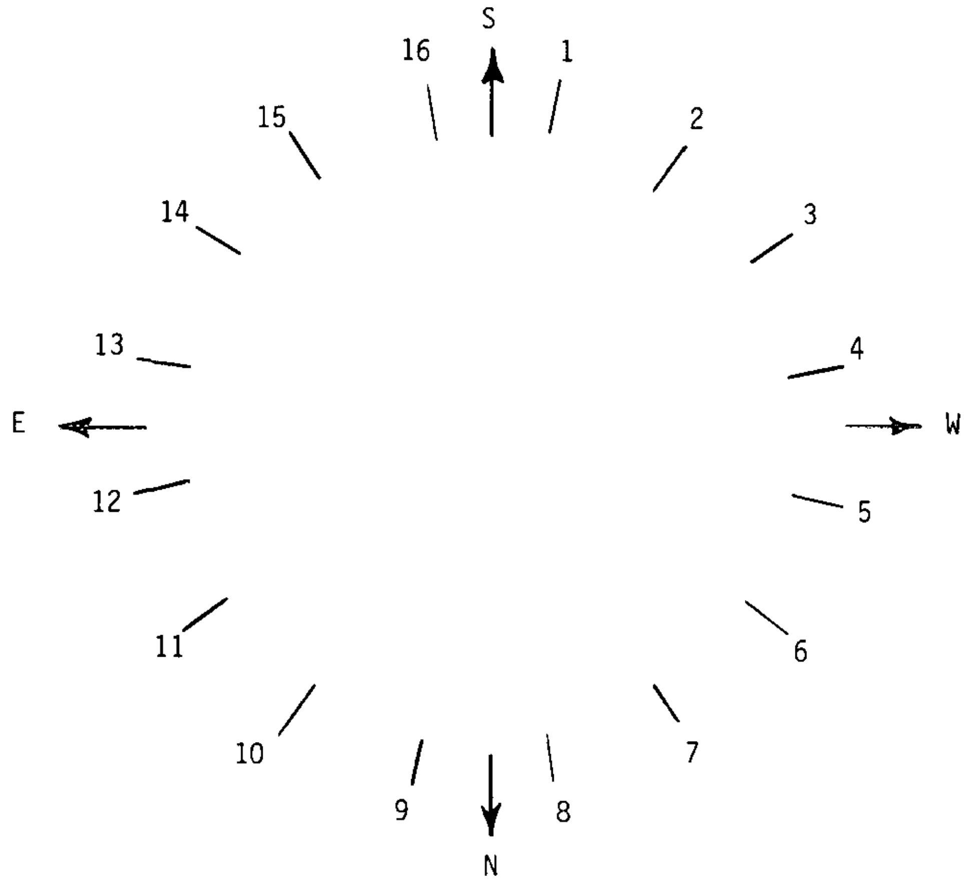
PLAN VIEW AT BASE OF NORTH TOWER SPIRE

LOCATION OF BROKEN WELDS AT HORIZONTAL ANGLE CONNECTIONS			
LEVEL NO.	AT VERTICAL NO.	LEVEL NO.	AT VERTICAL NO.
1	15	11	BETWEEN 1 - 2
2	15	11	BETWEEN 2 - 3
3	15	11	BETWEEN 5 - 6
4	1 (3 BROKEN)	11	BETWEEN 10 - 11
4	7, 15, 16	12	2, 5, 7, 16
6	10, 14, 15	12	BETWEEN 3 - 4
7	1, 5, 9, 13, 14	12	BETWEEN 16 - 1
10	5, 9, 13	13	1, 5, 10
11	2, 8	13	BETWEEN 4 - 5 (2 BROKEN)

NOTES:

- PLAN VIEW SHOWS NUMBERING SYSTEM OF SPIRE VERTICAL MEMBERS CLOCKWISE AROUND SPIRE.
- HORIZONTAL MEMBERS ARE REFERRED TO AS LEVELS NUMBERED FROM THE BOTTOM.

FIGURE 2-7



PLAN VIEW AT BASE OF SOUTH TOWER SPIRE

LOCATION OF BROKEN WELDS AT HORIZONTAL ANGLE CONNECTIONS			
LEVEL NO.	AT VERTICAL NO.	LEVEL NO.	AT VERTICAL NO.
3	10	11	ANGLE MISSING BETWEEN 5 - 6
4	1, 7, 12, 15, 16	12	1, 2, 5, 6, 9, 10
6	1 (ON LACING), 3, 4	12	ANGLE MISSING BETWEEN 15 - 16
6	5, 8, 10, 15	12	ANGLE IS CUT BETWEEN 14 - 15
7	1, 4, 5, 6, 7	13	2, 11, 12
8	1, 5, 6, 10	14	3, 15
9	1, 2, 6, 7, 15, 16		
10	1, 3, 11, 12, 13, 16		
11	2, 3, 4, 5, 9, 11, 15		

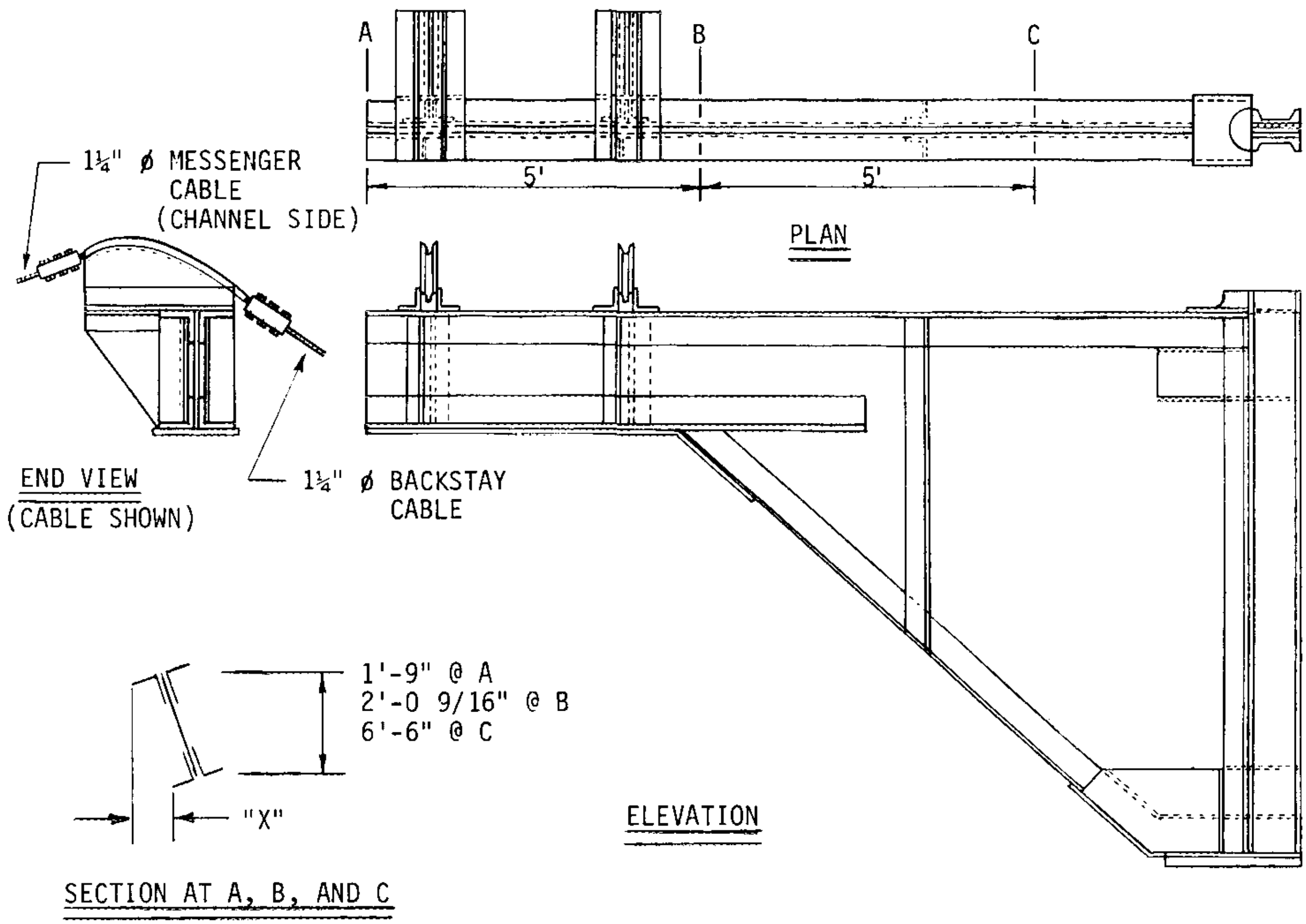
NOTES:
- PLAN VIEW SHOWS NUMBERING SYSTEM OF SPIRE VERTICAL MEMBERS CLOCKWISE AROUND SPIRE.
- HORIZONTAL MEMBERS ARE REFERRED AS LEVELS NUMBERED FROM THE BOTTOM.

FIGURE 2-7

MODJESKI & MASTERS ENGINEERS

Project: VERTICAL LIFT RAILWAY BRIDGE
Subject: CATENARY BRACKET ROTATION

Made by: MFB Date: 6-7-84
Checked by: GGC Date: 6-11-84
Sheet No. 1 of 1

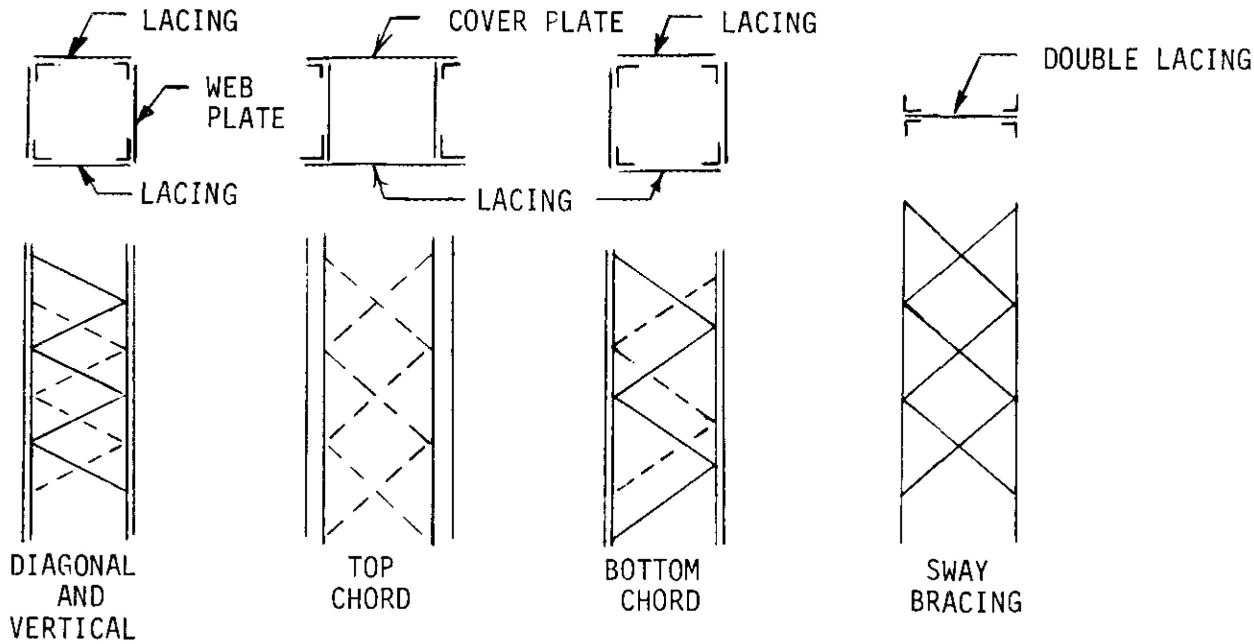


BRACKET	ROTATION DIRECTION	LOCATION	DIMENSION "X"	DEGREE OF ROTATION
NORTHEAST	SOUTH	A	1-3/4"	4.8 deg.
		B	3/4"	1.7 deg.
		C	1/2"	0.4 deg.
NORTHWEST	SOUTH	A	2-7/8"	7.8 deg.
		B	1-1/8"	2.6 deg.
		C	3/4"	0.5 deg.
SOUTHEAST	NORTH	A	1-7/8"	5.1 deg.
		B	7/8"	2.0 deg.
		C	3/4"	0.5 deg.
SOUTHWEST	NORTH	A	2-7/8"	7.8 deg.
		B	1-1/4"	2.9 deg.
		C	1/8"	0.1 deg.

NOTES: 1. ROTATION IS TOWARDS THE CHANNEL IN ALL CASES.

2. THE SOUTHEAST AND NORTHWEST BRACKETS ARE OPPOSITE HAND.

FIGURE 2-8



<u>LIFT SPAN TRUSS AND SWAY BRACING</u>

<u>MEMBER LACING BAR DETAILS</u>

<u>NOTES FOR ATTACHED TABULATION</u>:

1. LACING ON VERTICAL AND DIAGONAL MEMBERS ARE NUMBERED (DESIGNATION) FROM THE TOP, ON HORIZONTAL MEMBERS FROM THE EAST OR NORTH.

2. THE DOUBLE LACING ON THE TOP CHORD AND SWAY BRACING ARE NUMBERED AS PAIRS; THE BARS IN EACH PAIR ARE REFERRED TO AS UPPER OR LOWER AT THE POINT OF CROSSING.

3. N, S, E, W - NORTH, SOUTH, EAST, WEST
   U, L, B - UPPER, LOWER, BOTH

LIFT SPAN TRUSSES						
MEMBER LOCATION	QUANTITY	LACING BAR LOCATION				
		DESIGNATION	N	S	U	L
EAST TRUSS						
TOP CHORD U1'-U0'	1	4			X	
VERTICAL L1'-U1'	2	12, 13	X			
VERTICAL U2'-L2'	8	6, 8, 9, 10, 11, 12, 19, 20	X			
" " "	8	9, 10, 11, 12, 16,		X		
		18, 20, 25				
DIAGONAL U2'-L3'	3	4, 26, 34				X
TOP CHORD U2'-U3'	2	4, 5			X	
VERTICAL U4'-L4'	12	2, 3, 4, 5, 6, 8,	X			
		12, 14, 16, 18, 20, 26				
" " "	2	4, 14		X		
DIAGONAL L5'-U4'	1	60				X
TOP CHORD U4'-U5'	5	1, 2, 3, 4, 5,			X	
VERTICAL U5'-L5'	5	4, 5, 7, 8, 9,	X			
VERTICAL U5'-L5'	4	1, 2, 3, 34		X		
DIAGONAL L5'-U6'	3	1, 2, 4				X
TOP CHORD U5'-U6'	5	1, 2, 3, 4, 5			X	
VERTICAL U6'-L6'	16	6, 8, 9, 10, 11,	X			
		12, 16, 19, 20, 21,				
		26, 27, 28, 30, 31, 32				
" " "	6	5, 7, 10, 11, 12, 13		X		
DIAGONAL U6'-L7'	3	28, 35, 37				X
VERTICAL L7'-U7'	2	2, 3	X			
" " "	3	1, 2, 48		X		
VERTICAL L8'-U8'	10	8, 9, 10, 12, 14,	X			
		15, 16, 17, 18, 20				
" " "	8	4, 6, 7, 9, 11,		X		
		13, 14, 19				
DIAGONAL U8-L9	6	1, 2, 3, 4, 5, 6				X
VERTICAL L8-U8	10	7, 8, 10, 12, 13	X			
		14, 16, 17, 18, 20				
" " "	8	6, 8, 10, 11, 13		X		
		14, 15, 18				
DIAGONAL L7-U8	2	28, 46				X

LIFT SPAN TRUSSES (CONT.)						
MEMBER LOCATION	QUANTITY	LACING BAR LOCATION				
		DESIGNATION	N	S	U	L
VERTICAL L7-U7	1	2		X		
VERTICAL L6-U6	10	7, 8, 9, 10, 11	X			
		14, 15, 16, 17, 18				
VERTICAL L6-U6	7	6, 7, 8, 9, 10, 11, 12		X		
TOP CHORD U5-U6	5	1, 2, 3, 4, 5			X	
TOP CHORD U4-U5	5	1, 2, 3, 4, 5			X	
VERTICAL L4-U4	4	1, 2, 6, 8		X		
DIAGONAL U2-L3	3	3, 4, 6				X
VERTICAL L2-U2	5	6, 8, 10, 11, 12	X			
VERTICAL L2-U2	6	7, 8, 9, 10, 11, 12		X		
DIAGONAL L1-U0	1	20				X
WEST TRUSS						
TOP CHORD U0'-U1'	1	4			X	
TOP CHORD U1'-U2'	2	4, 5			X	
VERTICAL L2'-U2'	6	6, 8, 9, 10, 11, 12	X			
VERTICAL L2'-U2'	4	7, 8, 10, 11		X		
DIAGONAL U2'-L3'	13	1, 2, 6, 7, 8, 12, 15				X
		17, 19, 21, 25, 27, 34				
VERTICAL L3'-U3'	11	2, 6, 8, 10, 20, 21	X			
		26, 28, 33, 41, 42				
VERTICAL L3'-U3'	4	1, 3, 47, 48		X		
VERTICAL U4'-L4'	4	1, 2, 8, 9	X			
VERTICAL U4'-L4'	1	5		X		
DIAGONAL U4'-L5'	6	11, 12, 25, 41, 43, 59				X
TOP CHORD U4'-U5'	3	1, 2, 3			X	
DIAGONAL L5'-U6'	2	69, 70				X
TOP CHORD U5'-U6'	3	3, 4, 5			X	
VERTICAL L6'-U6'	1	6	X			
VERTICAL L8'-U8'	8	7, 8, 12, 13, 14	X			
		15, 19, 20				
VERTICAL L8'-U8'	3	6, 9, 11		X		
DIAGONAL L7-U8	3	24, 30, 50				X
VERTICAL L8-U8	10	9, 10, 11, 12, 13, 15	X			
		16, 18, 19, 20				

LIFT SPAN TRUSSES (CONT.)						
MEMBER LOCATION	QUANTITY	LACING BAR LOCATION				
		DESIGNATION	N	S	U	L
VERTICAL L8-U8	7	6, 8, 9, 10, 13		X		
		14, 16				
DIAGONAL L7-U6	3	42, 54, 60				X
" " "	3	7, 8, 50			X	
VERTICAL L6-U6	7	6, 8, 12, 13, 14, 16, 17	X			
" " "	4	6, 7, 8, 12		X		
DIAGONAL L5-U6	2	1, 2				X
TOP CHORD U5-U6	2	1, 5			X	
DIAGONAL U4-L5	10	2, 6, 9, 11, 13, 18,				X
		34, 45, 46, 64				
TOP CHORD U4-U5	3	3, 4, 5			X	
VERTICAL L4-U4	4	4, 5, 6, 7	X			
" " "	1	6		X		
DIAGONAL U2-L3	22	2, 3, 4, 5, 6, 7,				X
		9, 13, 14, 17, 18,				
		19, 20, 22, 29, 30,				
		36, 37, 38, 40, 41,				
		42				
VERTICAL L2-U2	3	8, 9, 12	X			
" " "	3	7, 10, 12		X		

LIFT SPAN SWAY BRACING

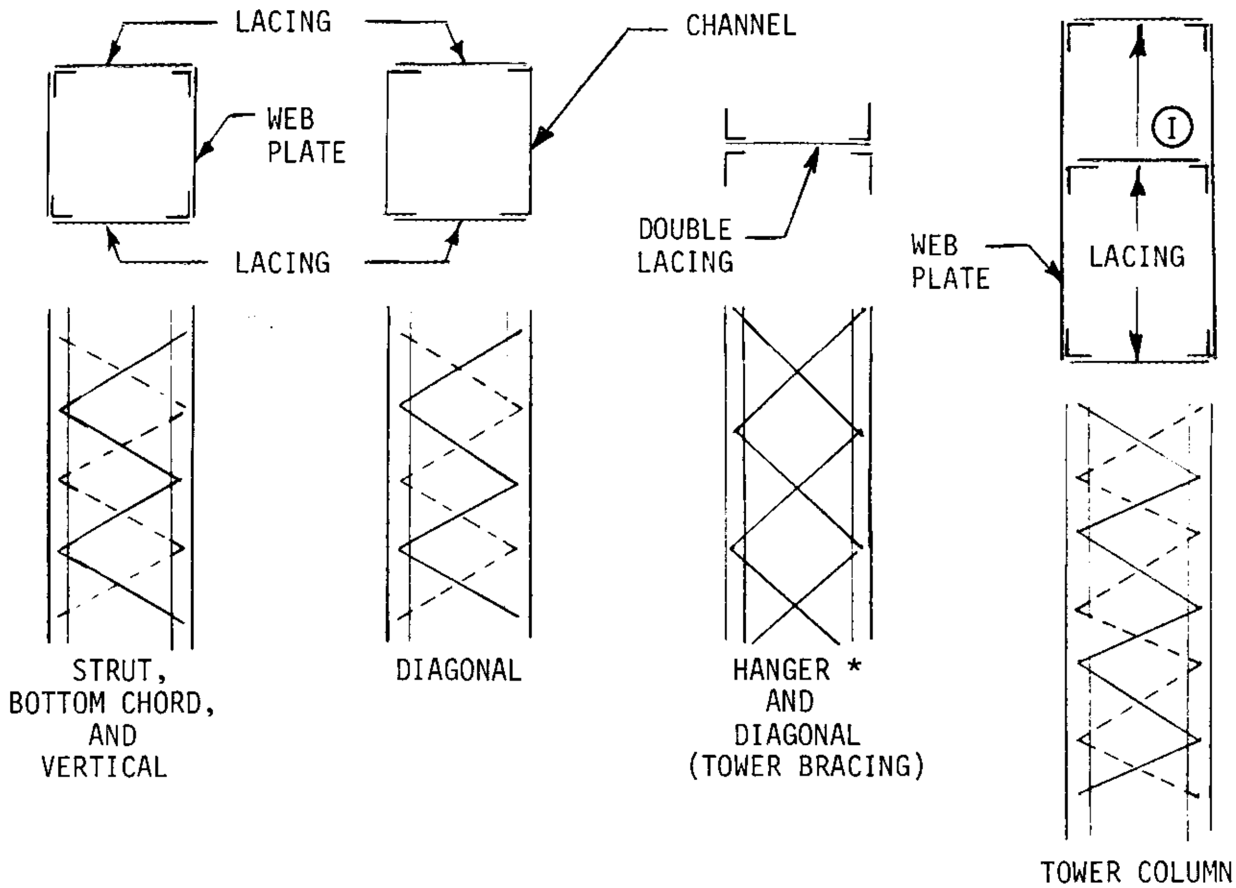
MEMBER	QUANTITY	LOCATION
P. P. 2		
KH	5	1U, 4B, 5B
GH	1	1L
GM	6	2L, 5U, 7B, 8B
KG	9	1L, 2L, 4L, 5B, 6U, 7U, 8B
KF	9	1U, 2L, 3U, 4L, 5B, 6L, 7B
FG	4	3L, 7U, 8B
FB	10	1B, 2B, 3B, 4U, 5L, 6L, 7L
GB	9	1B, 2B, 3U, 4U, 5U, 6L, 7U
GC	10	1U, 2B, 3L, 4L, 5L, 6B, 7L, 8L
HC	10	1B, 2U, 3B, 4B, 5B, 6U
AB	1	3L
BC	1	4U
CD	1	3L
P. P. 4		
MH	5	1U, 2L, 6U, 8L, 10L
MG	2	7L, 10U
KG	10	1L, 2L, 3U, 4B, 7B, 8U, 9B
KF	4	4L, 6L, 9U, 10U
FB	6	1L, 3L, 4L, 6L, 8B
GB	5	4U, 6U, 7U, 9B
GC	4	3L, 6L, 8U, 10U
HC	2	9L, 10L
P. P. 6		
AB	1	3L
HC	2	1L, 2L
GC	2	9L, 12L
KF	3	5U, 7U, 11U
KG	2	6L, 12U
MG	2	9L, 10L
MH	8	4L, 5B, 7L, 8B, 10B

LIFT SPAN SWAY BRACING - Continued

MEMBER	QUANTITY	DESIGNATION AND LOCATION
P. P. 8		
KG	2	9L, 12L
FB	2	1U, 11L
GC	2	7L, 13L
HC	6	1B, 3L, 4U, 6L, 10L
P. P. 8'		
HC	1	5L
GB	1	8U
MG	5	6U, 7U, 8L, 11U, 12U
KG	4	5B, 8U, 12L
KE	2	1L, 3L
P. P. 6'		
MH	3	6U, 10L, 11U
KG	2	6L, 12U
KF	1	9U
FB	5	4B, 6L, 9L, 11U
GB	6	1U, 3U, 4U, 5U, 6U, 9U
BC	1	1L
GC	5	5L, 3U, 9U, 12B
HC	6	4U, 5L, 7L, 8L, 9L, 10U
P. P. 4'		
MH	5	7B, 8U, 9L, 10U
MG	3	7L, 8L, 9L
KF	3	8U, 9U, 10U
FB	5	1L, 2L, 4U, 5L, 10L
GB	1	1U
BC	2	1B
GC	1	8L
HC	3	4U, 6U, 7L

LIFT SPAN SWAY BRACING - continued

MEMBER	QUANTITY	DESIGNATION AND LOCATION
P. P. - 2'		
AB	2	1L, 3U
FB	6	1U, 2L, 5B, 6L, 7L
GB	8	1U, 2L, 3U, 4L, 6L, 7U, 8U
HC	4	4B, 5U, 6L
MH	3	4U, 5U, 6U
MG	6	1U, 5B, 6L, 7B
KG	5	4L, 6L, 7B, 8L
KF	8	1U, 3U, 4L, 5B, 6B, 7U



APPROACH SPAN TRUSS AND TOWER LACING BAR DETAILS

NOTES FOR ATTACHED TABULATION:

1. LACING ON VERTICAL AND DIAGONAL MEMBERS ARE NUMBERED (DESIGNATION) FROM THE TOP, ON HORIZONTAL MEMBERS FROM THE EAST OR NORTH.

2. AN ASTERISK (*) INDICATES THE DOUBLE LACING ARE NUMBERED AS PAIRS WITH THE BARS REFERRED TO AS UPPER OR LOWER AT THE POINT OF CROSSING.

3. N - NORTH E - EAST U - UPPER
S - SOUTH W - WEST L - LOWER
I - TOWER COLUMN INTERIOR LACING (SEE ABOVE)

NORTH APPROACH SPAN AND TOWER								
MEMBER LOCATION	QUANTITY	LACING BAR LOCATION						
		DESIGNATION	U	L	N	S	I	
TOWER:								
(EAST SIDE)								
STRUT A1-A0	4	20, 21, 24, 29		X				
DIAGONAL B0-N	3	1, 4, 5		X				
STRUT B0-B1	1	8		X				
(WEST SIDE)								
DIAGONAL B0-N	2	1, 18		X				
DIAGONAL P-B0	4	8, 10, 11, 19		X				
DIAGONAL P-B1	3	1, 3, 15		X				
DIAGONAL C1-P	14	2, 3, 4, 5, 7,	X					
		10, 11, 12, 14, 15,						
		20, 21, 23, 24						
DIAGONAL C1-P	9	1, 2, 3, 5, 12,		X				
		15, 16, 17, 18						
TOWER COLUMN C1-B1	2	10, 35				X		
TOWER COLUMN C1-B1	8	30, 34, 37, 38,					X	
		39, 40, 46, 50						
(SOUTH SIDE)								
DIAGONAL M-A0 (W)*	1	1		X				
DIAGONAL M-A0 (E)*	3	2, 3, 8	X					
HANGER K-M*	2	1	REPLACE BOTH					
HANGER K-M*	1	2	REPLACE EAST BAR					

MODJESKI & MASTERS ENGINEERS

Project VERTICAL LIFT RAILWAY BRIDGE
Subject LACING BAR DEFICIENCY
TABLE 2-2

Made by KMK Date 7/10/84
Checked by GGC Date 7/16/84

NORTH APPROACH SPAN AND TOWER

MEMBER LOCATION	QUANTITY	LACING BAR LOCATION				
		DESIGNATION	N	S	U	L
SPAN:						
(EAST TRUSS)						
CHORD L2-L1	5	14, 20, 22, 30, 31				X
CHORD L3-L2	3	1, 35, 36				X
DIAGONAL U2-G	2	11, 17				X
DIAGONAL U3-G	1	20				X
DIAGONAL G-L3	3	11, 12, 16				X
VERTICAL U3-L3	4	4, 13, 24, 33	X			
VERTICAL U3-L3	1	22		X		
CHORD L4-L3	2	1, 2				X
(WEST TRUSS)						
CHORD L2-L1	1	37			X	
VERTICAL U2-L2	1	9	X			
DIAGONAL U2-G	8	2, 4, 5, 7, 11,			X	
		12, 15, 19				
DIAGONAL U2-G	6	1, 3, 7, 11, 13, 17				X
DIAGONAL G-L3	2	6, 10				X
VERTICAL U3-L3	5	5, 8, 22, 42, 44	X			
VERTICAL U3-L3	2	26, 27		X		
DIAGONAL U3-F	1	21				X
DIAGONAL F-L3	1	7			X	
DIAGONAL F-L3	2	21, 23				X
DIAGONAL U4-F	1	9			X	
DIAGONAL U4-F	3	1, 7, 8				X
VERTICAL U4-L4	6	8, 12, 16, 41, 43, 45	X			
VERTICAL U4-L4	5	10, 18, 27, 29, 31		X		
DIAGONAL U3-G	2	10, 11				X
* (NORTH PORTAL)						
MEMBER B-C	2	8			X	X
MEMBER C-D	3	1, 2, 3				X
STRUT U4 (UNDERSIDE)	4	7, 8			X	X
*ALL DOUBLE LACING						

SOUTH APPROACH SPAN AND TOWER							
MEMBER LOCATION	QUANTITY	LACING BAR LOCATION					
		DESIGNATION	U	L	N	S	I
TOWER:							
(EAST SIDE)							
TOWER COLUMN A1-U1	2	9, 13			X		
TOWER COLUMN B1-A1	3	1, 42, 50			X		
TOWER COLUMN B1-A1	22	1, 2, 4, 5, 6 8, 9, 10, 11, 13 16, 17, 18, 19, 21, 29, 32, 33, 34, 36, 37, 45					X
DIAGONAL B1-N	2	3, 4		X			
TOWER COLUMN C1-B1	1	1			X		
TOWER COLUMN C1-B1	3	1, 6, 8				X	
TOWER COLUMN C1-B1	11	1, 2, 10, 14, 18, 20, 32, 36, 40, 42, 48					X
DIAGONAL C1-P	10	3, 4, 5, 6, 13, 18, 20, 23, 25, 26	X				
DIAGONAL C1-P	5	1, 2, 3, 5, 6		X			
(WEST SIDE)							
TOWER COLUMN C1-B1	1	1			X		
TOWER COLUMN C1-B1	2	1, 2					X
DIAGONAL C1-P	4	1, 2, 17, 21		X			
(NORTH SIDE)							
DIAGONAL B0-M (W)*	1	10	X				
*DOUBLE LACING							

TABLE 2-2

SOUTH APPROACH SPAN AND TOWER						
MEMBER LOCATION	QUANTITY	LACING BAR LOCATION				
		DESIGNATION	N	S	U	L
SPAN:						
(EAST TRUSS)						
CHORD L0-L1	1	32			X	
CHORD L0-L1	1	25				X
CHORD L1-L2	7	4, 5, 6, 20,				X
		31, 33, 36				
CHORD L2-L3	5	8, 12, 21, 28, 34				X
CHORD L3-L4	2	34, 35			X	
CHORD L3-L4	7	2, 8, 21, 25,				X
		27, 31, 32				
(WEST TRUSS)						
VERTICAL U2-L2	1	25	X			
VERTICAL U3-L3	1	30	X			
CHORD L3-L4	1	18			X	
CHORD L3-L4	1	2				X
DIAGONAL F-U4	1	7				X

PART V-3

ELECTRICAL EQUIPMENT

PART V-3 - ELECTRICAL EQUIPMENT

The bridge electrical system was inspected for proper operation, excessive deterioration, hazardous conditions, and compliance with the National Electrical Code. Most of the existing electrical equipment, such as the control circuit switchboards, control console, limit switches, etc., should be considered non-renewable. That is, while they may presently be in good operating condition, replacement parts are in general no longer obtainable. Rather than simply replacing individual components as a remedy to obsolescence, it is recommended that equipment be grouped according to systems or subsystems, and replaced en masse.

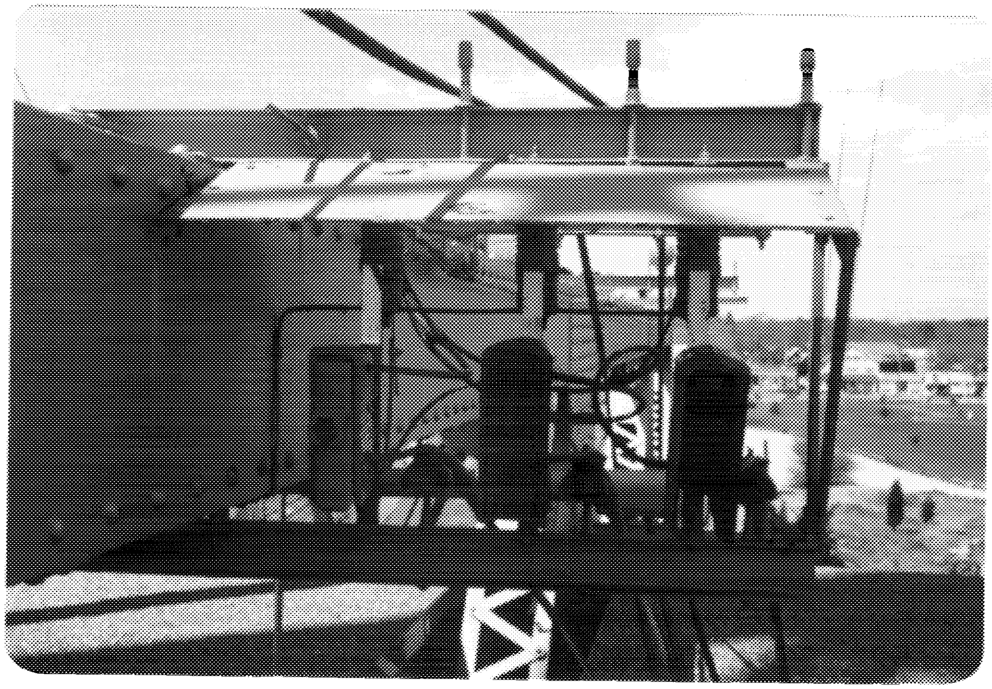
In general, the electrical system for normal bridge operation is in good condition. Recommendations for the electrical system will be found at the end of this Part. Tabulated measurements, the operating tests, and other quantitative data will be found in Appendix A.

The results of the diesel engine and the high voltage transformers/switch gear inspections are incorporated into this Part, with actual copies of Cooper Energy Services' and Westinghouse Electric's reports being located in Appendix A.

Incoming Power - Normal and Emergency

Commercial Service. The commercial power source is a 4,160 volt, 3-phase, 3-wire overhead service. The aerial service conductors are suspended from the service pole to the support brackets above the control house roof, and terminate on high voltage fuses above the roof. High voltage lead-in cables then extend down and into the new air break high voltage disconnects in the transformer room. These two sets of air break disconnects then feed the 150 KVA 480 volt and the 15 KVA 280Y/120 volt transformer banks. The 480 volt transformers provide power mainly for the bridge machinery, and the 208Y/120 volt transformers provide local lighting and heater power.

With the commercial power off, the aerial service cables were inspected and found to be in very good condition. The cables were meggered and yielded very good insulation resistance values, in excess of 1,000 megohms. However, the high voltage fuse assemblies on the control house roof are aged and deteriorating. When the fuses were opened by one of the bridge operators, one of the porcelain fuse assemblies crumbled (see Photograph I-28). The line side cable lug was attached to the load side lug by the bridge operator as a temporary repair. This bypassing of one high voltage fuse is not considered a code violation or safety hazard, since the aerial service cables are also protected by the fuses on the service pole. These roof-mounted fuses are actually redundant, and serve as more of a maintenance convenience than a necessity.



Photograph I-28 - High voltage fuse assemblies on control house roof. Note broken unit, far right.

The down leads and the air break high voltage disconnect switches were inspected and found in good condition. Some minor adjustments to the disconnects are recommended, and are included in the final list of recommendations. The 15 KVA transformer bank was inspected for general condition of wiring, oil analysis, and electrical measurements of the transformers themselves. The high voltage primary wiring was found to be deteriorating. Oil samples were taken and forwarded to the Westinghouse Laboratory for analysis. The oil was also tested on-site for polychlorinated biphenyl (PCB) content, and yielded readings less than 50 parts per million. This oil is therefore classified non-PCB. More complete data from the oil analysis is tabulated in the Westinghouse report in the Appendices. It should be noted that, while this transformer oil was found to be in overall good condition, the actual oil level in the transformer tanks is not known, since the transformers are not provided with sight glasses. This is considered in the recommendations. The 15 KVA transformers were in otherwise good condition.

The 150 KVA transformer bank was also inspected for general condition of wiring, oil analysis, and electrical measurements on the transformers. These transformers were also found in overall good condition. However, the oil level was low and the analysis found it in need of reconditioning or replacement. This oil is also classified non-PCB.

The bridge was operated numerous times from the commercial service. In all cases, the commercial service performed satisfactorily. The results of these operating tests are tabulated in the Appendix.

Emergency Engine-Generator. The main generator, the main exciter, and the auxiliary generator were inspected visually and with electrical measurements (meggering) of the winding insulation resistance. In addition, the diesel engine was inspected for wear and proper operation, including its various appurtenant accessories.

The main generator access covers were removed, the slip rings and brushes were inspected, the windings were meggered, and both front and rear bearing oil cups were checked. The generator is in good condition. The field and stator windings meggered at 44 and 60 megohms, respectively. The slip rings and brushes appeared in good condition. However, no oil was observed in the bearing oil cups, although the cup interiors appeared wet. When questioned, the bridge operators reported no knowledge of their existence, since they are concealed when the generator access covers are in place.

The main exciter commutator and brushes were inspected. The wiring was temporarily disconnected while the windings were being meggered. The machine appeared in good condition. The rotor and stator meggered at 1,000+ and 50 megohms, respectively.

The auxiliary generator was inspected. The slip rings and brushes appeared satisfactory. With the rotor and stator disconnected, they meggered at 30 and 700 megohms, respectively. This generator appears to only be used to operate the various intake and exhaust louver motors in the generator house. When the engine-generator set was operating, the louvers failed to open. The auxiliary generator appeared to be operating and preliminary checks indicated that output voltage was present. However, further trouble shooting was beyond the scope of this inspection.

The auxiliary exciter was inspected, including its commutator, brushes, and windings. The exciter appeared in good condition, and when disconnected, the rotor and stator windings meggered at 170 and 1,000+ megohms, respectively.

The generator control and switchgear cabinet was inspected. Although in fairly good condition, internally there is evidence of excessive moisture, probably from condensation during the summer months. Some insulation mold and mildew, as well as terminal and contact corrosion was noticed.

The generator was operated under load by raising and lowering the lift span. Although the voltage regulator appeared a bit sluggish in comparison to modern electronic regulators, the existing electrical-mechanical voltage regulator appeared to perform as well as could be expected, considering the type and era of manufacture. Operation was observed to be satisfactory for this application. However, after several operations of the bridge, the alarm horn sounded, presumably for high water temperature. Further operation of the bridge with the engine-generator was therefore discontinued.

The diesel engine was later inspected by the manufacturer's maintenance mechanics. The engine side cover plates were removed. The lower cylinder liners were checked, and one rod bearing and one main bearing were dissembled and checked. These parts were found to be in good condition, with very little wear.

Crank shaft alignment readings were taken for four angular positions at each of the six cylinders, using a crank shaft deflection gauge. A high positive deflection reading at the No. 1 cylinder was determined to be caused by excessively tight fan belts. The belts were adjusted and the problem alleviated. The deflection measurements were repeated and found satisfactory.

The engine was rotated by hand to check the timing chain and oil pump drive gear. Both were in good condition. The timing chain tension was adjusted. The intake and exhaust valve tappets were set at .015 and .018 inches, respectively; and some of the air start valves were adjusted.

The engine-generator was used to power the bridge during raising and lowering of the lift span, so the engine could be observed under load. The engine easily handled the load. The overspeed shutdown was checked and found inoperative. This is an important safety device on a diesel engine. The alarms for low oil pressure, high water temperature, and high oil temperature were checked and adjusted. As noted previously, the automatic intake and exhaust louvers did not operate.

In addition, the emergency start and stop valves were painted over, with the excess paint rendering them inoperative. The handle for the lube oil strainer was missing and reportedly never operated by the bridge operators. This is intended to be used each time the engine is run.

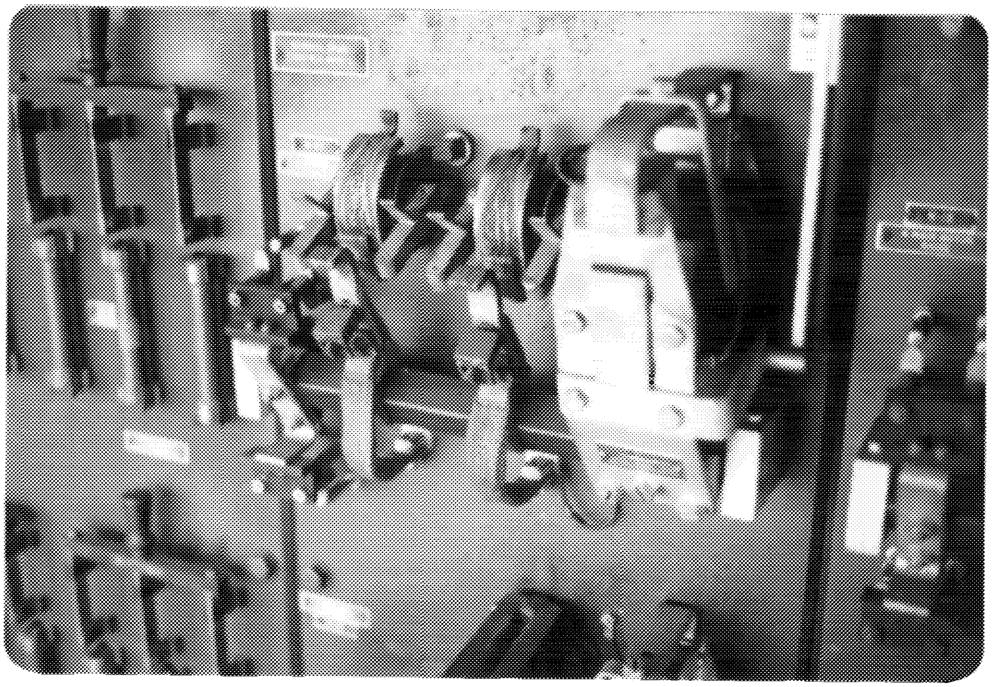
The cooling system was checked and appeared to be operating satisfactory, with the exception of the water jacket thermostat. Maximum temperature of water out of the engine was only 140 Degrees F.

Generally, the engine was in good condition and still young in terms of wear. Corrective recommendations appear at the end of this Part.

Main Switchboard

The main switchboard is located in the control house, and consists of a free-standing board of a phenolic-type material on which is surface-mounted most of the power and control contactors and relays, knife switches, fuses, etc. in an open live-front configuration. This open live-front arrangement exposes personnel to a 480 volt shock hazard, as they must walk uncomfortably close to it for access to the rest of the control house and elevator. Although this system presently provides satisfactory operation, most components are obsolete, and replacement parts are generally unavailable.

All arch chutes and covers were removed from all contactors and relays for inspection of the contacts and arcing horns. Most contacts were in fair to good condition. A few of the span traction and selsyn contactors exhibited heavy pitting on the contacts (see Photograph I-29). The auxiliary contact linkages on some contactors is excessively worn, and have reportedly interfered with bridge operation on occasion. Replacement parts for these contactors will probably have to be custom manufactured, since this type of equipment has been obsolete for quite some time. All contactor and relay coils were meggered and appeared in satisfactory condition.



Photograph I-29 - Selsyn excitation contactor with arc chutes removed to show pitting and scorching of the contacts and arcing horns.

All fuses on the main switchboard were checked for continuity and voltage drop. With a few exceptions, most were found to be in satisfactory condition. Several fuses had been removed and not replaced, six fuses were bad (open), one fuse was replaced with a larger ampere rating, and several fuses were either unlabeled as to purpose or unmarked as to rating. See the tabulation in Appendix A for more specific information. In general, however, these fuse deficiencies were confined to equipment and circuits no longer used.

The secondary resistors for the wound rotor traction motors were mounted over the main switchboard. These resistors were inspected for signs of warping, loose terminal connections, and loose or missing mounting bolts. One mounting bolt was missing. Otherwise, the resistors exhibited no more than normal paint discoloration, and were found to be in very good condition.

The relatively new circuit breakers and switchgear at the end of the main switchboard were inspected and appeared to be in good condition.

The interconnecting wires, bus bars, terminals, and various other miscellaneous apparatus on the back of the switchboard were inspected and found to be in good condition. Terminals and support hardware were checked for tightness.

Lower megger readings of substantially less than 100K were found on several of the power and control circuits. These were generally the span locks motors and some of the limit switches. The fact that this equipment is operating satisfactory diminishes the urgency with which such low readings might otherwise be viewed. However, this situation does warrant attention, as summarized in the recommendations.

The control system was inspected and observed during numerous operations of the bridge. The system was found to provide very smooth operation, with no measurable skew. Timing of accelerating steps was found satisfactory. Interlocking was found somewhat deficient. The brakes hand release switches were generally not operable due to excess paint, and there were no brakes released interlocking or indication whatsoever. However, in spite of the interlocking deficiencies, this is a well-maintained control system. This type of control system (stepped resistance), coupled with the power selsyn skew control scheme, has a proven history of reliability as a bridge drive system. It should be noted that the equipment is obsolete, but not necessarily the drive system philosophy.

Control Desk

The control devices on the desk were checked for proper operation. All indicating instruments on the desk appeared to be functioning properly during bridge operation. The duplicate set of controls on the left side of the desk are dedicated to the emergency drive system, which does not appear to be operational. Interlocking to the Railroad signal system worked correctly.

All meters on the elevated panel above the desk were checked during bridge operation. The power selsyn transfer wattmeter never moved off zero, and appears to be non-operational. The voltmeters were checked against our Simpson Model 265 VOM, and found to be accurate. The ammeters were checked against our Amprobe Model RS-3 ammeter and found to be somewhat inaccurate. The north and south motor ammeters read approximately 15 and 24 percent high, respectively, when the motors were drawing about 100 amperes.

Limit Switches

The normal main span limit switches, the skew limit switch, and the height and skew transmitters in the towers were checked for cam and contact settings, contact wear, and drive gear wear. Except for some minor pitting on a few of the contacts, this equipment was in overall good operating condition.

The seating limit switches were inspected and found to be in good condition, except for water collecting in the bottoms of the housings.

The rail lock limit switches were checked. Water and oil was found in the bottoms of these switches also.

The hand release limit switches on the thrustor brakes were found to be sluggish, and sometimes not operable. Too much paint on switch lever shafts appeared to be part of the problem as previously stated. It was also noted that there were no limit switches to interlock the control circuit for brakes released, or brakes set.

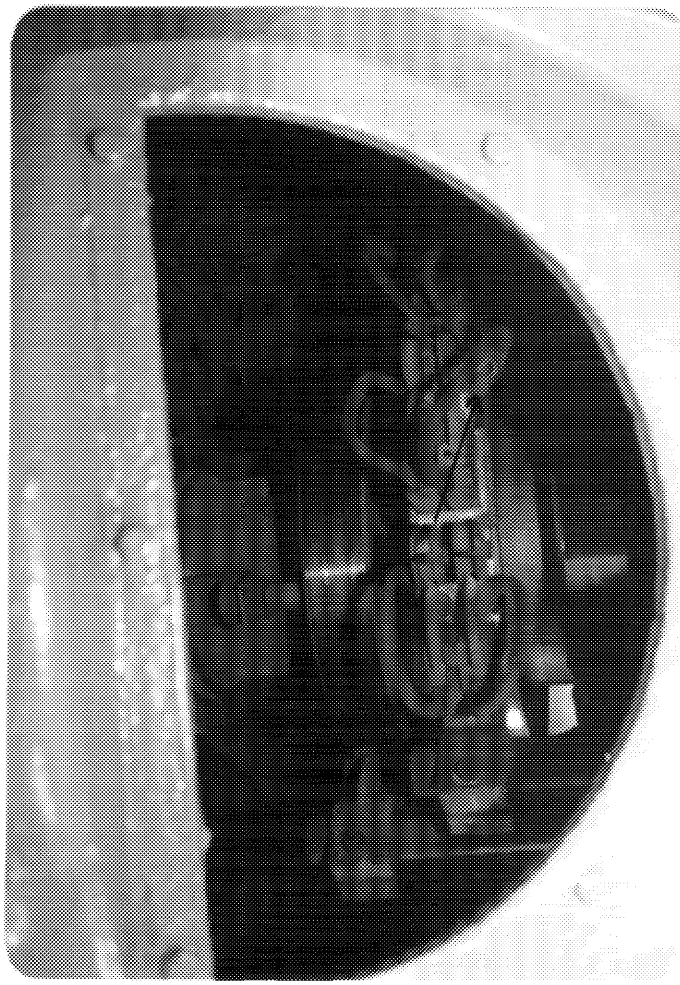
Cable Transfer Switch

The cable transfer switch in the south tower was inspected and appeared to be in good condition. Terminals were tight. Operation of the switch, however, was not observed. This switch is not used, since the emergency drive system is not operational. The operators reported they did not know how to operate this switch, and could not demonstrate its use during the inspection.

Span Drive Motors

The main span motors appeared to be in overall good condition, in spite of their age. Slip rings were mostly bright and brushes were seating properly. Some minor grooving was observed on the outboard slip ring of the west motor in the south tower. Also, both motors in the south tower and the east motor in the north tower were each found with one sheared terminal screw on their brush holders (see Photograph I-30). There are multiple brushes on each brush holder assembly for redundancy, so the motors continue to be operational.

The auxiliary drive motors apparently have not been operated for an extended period of time. Their slip rings are severely tarnished and coated with dirt and dust. These motors should not be operated until thoroughly cleaned, including the bearings, in a qualified shop.



Photograph I-30 - Loose wire terminal on drive motor brush holder assembly, resulting from sheared terminal screw.

Navigation Lights and Aerial Beacons

All marine navigation lights on the piers and on the lift span were inspected. The pier lights were in good condition, except for a little silver paint over-spray on some of the lenses. Several of the flashing navigation lights on the lift span were missing their sun shields, and the small mirrors intended to enable the operators to see them flashing, but were otherwise in satisfactory condition.

The aviation aerial obstruction beacons were inspected and found in good condition. The photocontrol is apparently non-operational, as the beacons operate continuously. Also, 200 watt incandescent lamps are being used, instead of the FAA recommended 620 or 700 watt incandescent lamps.

Wiring and Cables

Catenary Cables. The east and west aerial cable catenary systems were inspected visually for physical jacket and hardware condition, and electrically for conductor and insulation condition. The meggering was done from the main switchboard. In nearly all cases, they meggered satisfactory (see megger tabulations for exceptions).

The 1-1/4 inch diameter wire rope main messenger cables and their backstays at each tower and the 3/8 inch diameter secondary messenger cables between towers are in good condition. The inboard main messenger cable on the east side of the structure is slightly more taut between towers than the outboard cable (refer to Photograph II-51) and the inboard backstays are slightly more slack. No apparent problems have developed due to the unequal adjustment of the two cables.

The inboard backstay cable at the northwest catenary bracket is contacting the center secondary cable of five cables near the bracket (see Photograph I-31). The secondary cable should be disconnected at the bracket and placed on the opposite side of the backstay. The power/control cable should be wrapped with a protective shield if it will contact the backstay after moving the secondary cable.

Photograph I-31 - Contact between inboard backstay cable and secondary messenger at northwest cantilever bracket.

The galvanized coating on the messengers and backstays is beginning to show the effects of weathering by minor oxidation and point surface corrosion at locations in the crevices between strands. Near the towers all backstays have a light coating of primer paint at areas, apparently blown onto the cables during recent bridge painting operations. The inboard cable of the southeast backstay is coated with a dried substance near the south face of the tower. Primer paint exists on the surface of the coating.

On the east side of the lift span, at the third and fifth intermediate supports from the north tower, the respective east and west cast steel saddles for the main messengers are rotated against the support angles. The saddles at the first support and the east saddle at the sixth support are slightly rotated. The U-bolts are tight at the connections. Several of the support angles are corroded on the top surface at locations the galvanize coating is abraded.

At the fourth support bracket on the west main messengers, the single fastener in the connection of the second inboard secondary messenger to the suspension hook is loose.

Generally, all the grade clamps that support the electrical conduits are corroded at the edges, but are still functioning (see Photograph II-206). Near the northwest catenary bracket, a rubber shield was not installed between a grade clamp and the conduit and the edge of the clamp is penetrating into the conduit. Between the fifth support bracket of the west main messengers and the south tower many of the galvanized shields are missing or displaced from the ring supports for the single communications or signal conduit (see Photograph II-207).

Exposed Tower Cables. The exposed vertical cables on the towers were inspected for physical condition of the outer jacket and for electrical condition of the conductor and insulation. These cables were in satisfactory condition.

Control House and Machinery Room Wiring. Cables and wiring between the switchboard and control desk were in good condition. Some of this wiring is relatively new.

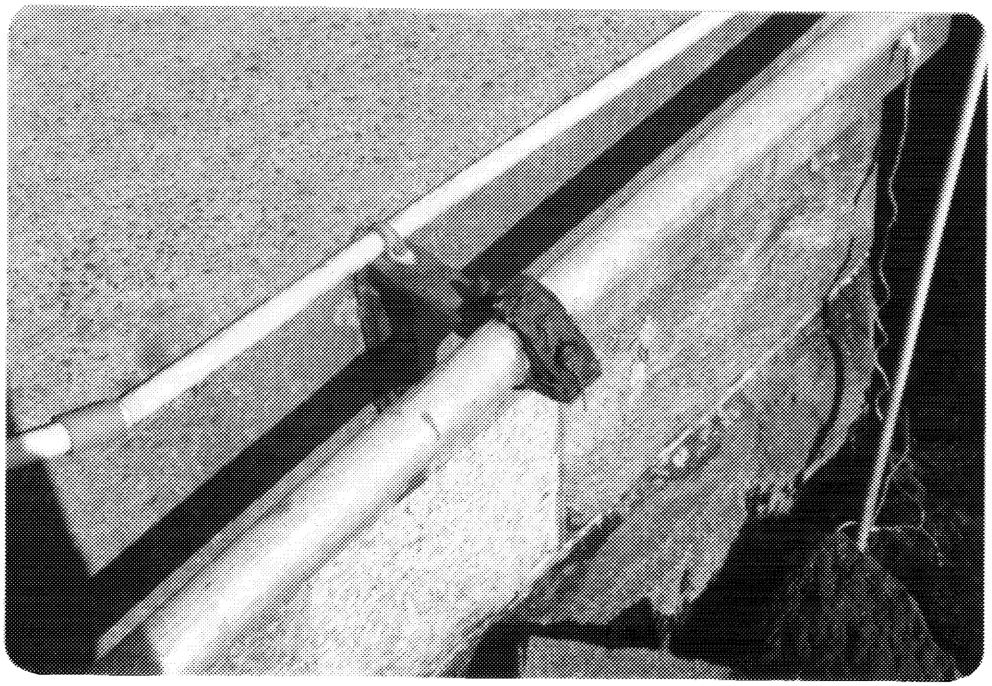
The panelboard circuits in the control house and both tower machinery rooms were meggered, and found to be in satisfactory condition. Results are tabulated in the Appendix.

Some of the more recently installed panelboard circuits appear to feed the radio equipment in the machinery rooms, and are pre-arranged in a somewhat haphazard manner.

Miscellaneous Exposed Wiring. Miscellaneous exposed wiring, mostly appearing to be communication wires, were found strung on the north tower bottom. This wiring apparently is abandoned.

Tower and Lift Span Conduits

North Tower and Pier. Some conduits were rusted through in spots. In some cases, the conduit appeared good, but the support clamps were badly rusted. Also, some electrical boxes appear to have been abandoned in place. The plastic conduit carrying the ground wire into the riprap at the pier bottom is coming apart at the couplings, and generally inadequately supported (see Photograph I-32). Surplus ground wire is inappropriately kinked and bent in a haphazard manner. Such bends and kinks generally deteriorate the grounding effectiveness for lightning protection.

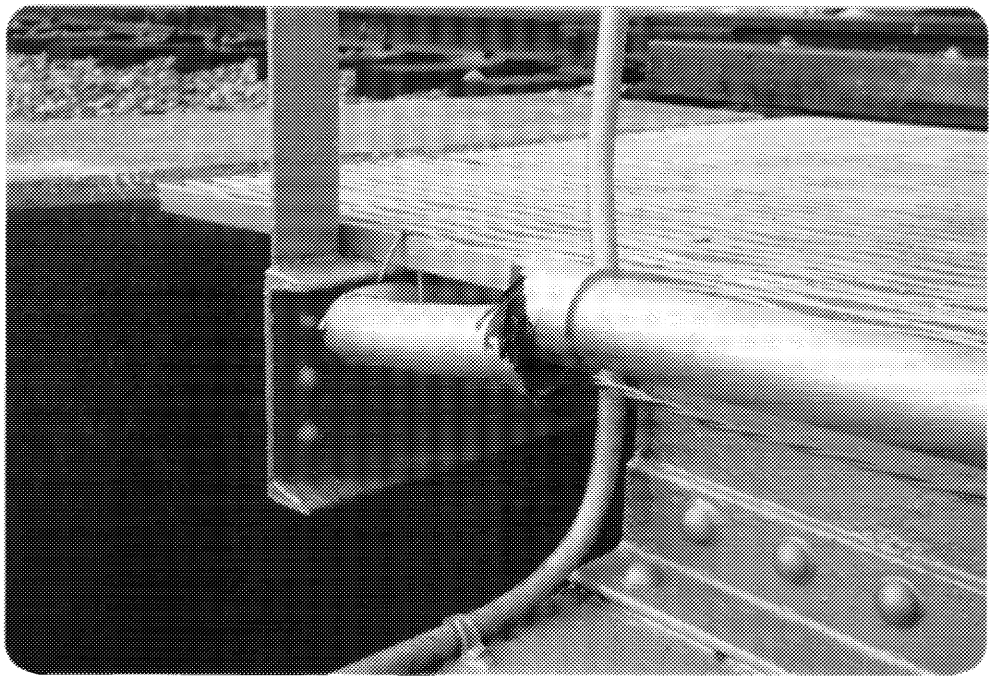


Photograph I-32 - Broken plastic conduit and corroded support clamp on Abutment D.

Conduits at Abutment D were also in generally unsatisfactory condition. Broken conduit body, improper conduit supports, and improper conduit termination were found.

South Tower and Pier

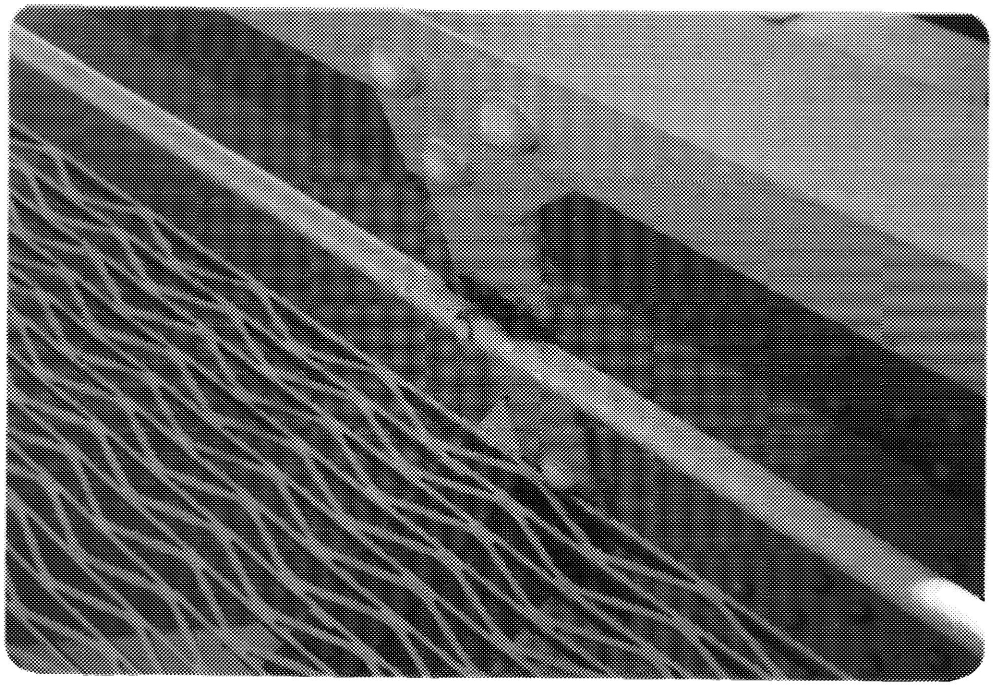
Conduits on the south tower and pier were generally in satisfactory condition, with a few exceptions. The plastic conduit on the tower span was broken in several places (see Photograph I-33). This conduit was improperly supported, using plastic cable ties. Also, a conduit body cover was missing. In some places, conduit clamps were rusted. The two large junction boxes at the bottom of the south tower were in good condition, except for some missing cover bolts.



Photograph I-33 - Broken and improperly supported plastic conduit on south tower span.

Lift Span

Conduits on the top chord of the lift span were in satisfactory condition. However, conduits at stair and walkway levels were suffering from severe rusting at and of the support clamps (see Photograph I-34).



Photograph I-34 - Corroded conduit along the lift span walkway.

Air Horns

The air horns and compressors were inspected. The horns appear quite old, but are in fair condition. The compressor motors are relatively new and appear in good condition. The motors were meggered and yielded excellent insulation values, each in excess of 1,000 megohms. The air controls for the horns are obsolete, but still function satisfactorily.

Recommendations

Incoming Commercial Power

1. Replace the high voltage fuse assemblies on the control house roof.

2. Contact resistance should be lowered on both General Electric 5 KV load break disconnect switches in the transformer room by tightening the moving main contact gap.

3. Replace the high voltage primary wiring to the 15 KVA transformer bank.

4. The three 15 KVA transformers should each be taken out of service, covers removed, and oil level visually checked.

5. As a preferred alternative to 4. above, replace the three aged 15 KVA oil-filled transformers with new dry-type transformers, thus eliminating future oil maintenance and the potential fire hazard associated with oil transformers.

6. The three 150 KVA transformers should each be taken out of service and their oil changed.

7. As a preferred alternative to 6. above, replace the three aged 150 KVA oil-filled transformers with new dry-type transformers, thereby eliminating the future oil maintenance and potential fire hazard associated with oil transformers.

Emergency Engine-Generator

1. Lubricate main generator bearings via the oil cup fill tubes located under the access covers at both ends.

2. Repair intake and exhaust louver operating motor circuit.

3. Install strip heater in generator control/switchgear cabinet to combat condensation and dampness.

4. Repair the diesel engine overspeed safety shutdown.

5. Repair or replace the emergency start and stop valves which are presently inoperative due to excess paint.

6. Replace the missing handle for the engine lube oil strainer and incorporate its use into the engine operation procedure.

7. Repair or replace the water jacket thermostat.

Main Switchboard

1. Burnish pitted contacts on contactors, and replace cracked or broken arc chutes (if replacement parts can be obtained).

2. Periodically re-inspect auxiliary contact linkages on contactors and rebuild when necessary.

3. Replace the various power circuit wiring and/or motors as necessary to correct the low megger readings for the south rail lock and lower span lock motor.

4. Isolate and correct the low megger readings (below 0.5 megohms) obtained from the skew limit switches, lock control, main span limit switch, railroad signal interlocking, and normal span control interlocking. (See readings noted in the tabulation in the Appendix A).

5. Replace faulty and inappropriately sized fuses (see tabulation in Appendix A).

6. Replace missing mounting bolt in resistor mount.

7. The bridge control system, in general, is antiquated. This control system, including the main switchboard, should be replaced with a modern, enclosed, automatic (single push button) system. This would not only eliminate the replacement parts procurement problem, but also the shock hazards presented by the existing open front, exposed contact type of equipment.

Control Desk

1. Repair power selsyn transfer wattmeter.

2. Recalibrate the ammeters.

3. Replace control deck (or at lest the control panel and metering) at such time as the control system is replaced, as recommended in 5. above under "Main Switchboard".

Limit Switches

1. Clean and dry the span seating limit switches. Drill a 3/16 inch drain hole in bottom corner of each switch.

2. Periodically inspect the main span limit switches (rotary cam type) in the north machinery house, and the skew limit switches in both machinery houses. Dress the contacts as necessary.

3. Clean and dry the rail lock limit switches. Drill a 3/16 inch drain hole in bottom corner of each switch.

4. Replace all brake hand release limit switches.

5. Provide brakes released limit switches on all thruster brakes at such time as control system is replaced; it may not be feasible with existing equipment. Correct control interlocking should prohibit span drive motor operation until brakes are released, except for the drag brake function.

Navigation Lights and Aerial Beacons

1. Clean all paint spray off of navigation light lenses.

2. Replace sun shields and mirrors on the flashing span mounted navigation lights.

3. Replace aerial beacon lamps with the correct type approved by the FAA for aerial obstruction marking (620 or 700 watt incandescent).

Catenary Cables

1. At the northeast catenary bracket, the center secondary cable (of five cables), which is contacting the inboard backstay cable, should be disconnected from the bracket and placed on the opposite side of the backstay. Wrap the power/control with a protective shield if necessary for abrasion or rubbing protection after the above relocation.

2. The catenary cable system should be inspected every two or three years to monitor the minor corrosion noted on the support angles, the grade clamps, and the wire ropes.

Tower and Lift Span Conduits

1. Replace rusted conduits on the north tower bottom and on the north tower span.

2. Repair the plastic conduit carrying the ground wire and the conduit supports at the north abutment. Eliminate surplus ground wire and all unnecessary bends and kinks.

3. Repair broken conduit body, provide proper conduit supports, and terminate conduit with an insulating bushing oriented downward at north abutment.

4. Replace broken plastic conduit with galvanized steel conduit and provide proper conduit supports on the south tower span.

5. Replace missing conduit body cover and miscellaneous rusted conduit support clamps.

6. Replace rusted conduits and supports along the lift span walkway and stairways.

7. Remove miscellaneous abandoned loose wires at tower bottoms.

PART V-4

COUNTERWEIGHTS

PART V-4 - COUNTERWEIGHTS

Main Counterweights

The main counterweights are constructed of steel boxes filled with concrete. Steel hanger plates attached internally project vertically from the concrete to connect to the counterweight ropes. Four wells or chambers exist in each counterweight to place small concrete blocks for adjusting the weight of the counterweight (see Photograph II-217).

The exterior metalwork surfaces of the counterweights are in good condition. Occasional corrosion areas exist on the surfaces. On the top surfaces of the units, caulking was placed at the interface of the concrete caps and the hanger metalwork. The caulking is deteriorated at areas and should be renewed.

The concrete cap of the north counterweight is in good condition; however, major spalled and unsound areas exist in the cap of the south main counterweight (see Photograph II-218 and Figure 4-1). The deteriorated concrete of the cap should be repaired and the upper surfaces of both counterweights cleaned and sealed.

The drainage gutters on the units are generally free of debris. The screens at the bottom of the exterior vertical gutter drains have been removed and the drains are open.

The well covers are adequately painted on the upper surface; however, poor paint cover and excessive corrosion was noted on the underside of two covers removed (see Photograph II-219). The northwest and southeast covers of the north and south counterweights, respectively, were removed for inspection of the adjustment chambers. Both chambers were found to be dry and the concrete in good condition, except the west side of the southeast chamber (see Photographs II-220 and 221). Hairline cracks with leaching stains exist near the top of the chamber which is adjacent to the spalled area of the cap. Adequate room exists in each compartment for the placement of additional adjustment blocks.

Fastener nuts for securing the well covers on the south counterweight have severe section loss and should be replaced.

Auxiliary Counterweights

The auxiliary counterweights consist of rectangular steel boxes filled with concrete and are used to compensate for the shifting weight of the counterweight ropes as the span is opened and closed (see Photograph II-217). Both auxiliary counterweights are in good condition. The upper surfaces of the units are covered with grease apparently dropped while lubricating the counterweight ropes.

Minor section loss exists at the base of the hanger metalwork used to support the counterweight when changing the ropes. The paint is deteriorated on the members (see Photograph II-222).

The condition of the main and auxiliary counterweight ropes and the counterweight guide shoes is discussed in Part V-5 - Mechanical Equipment.

Recommendations

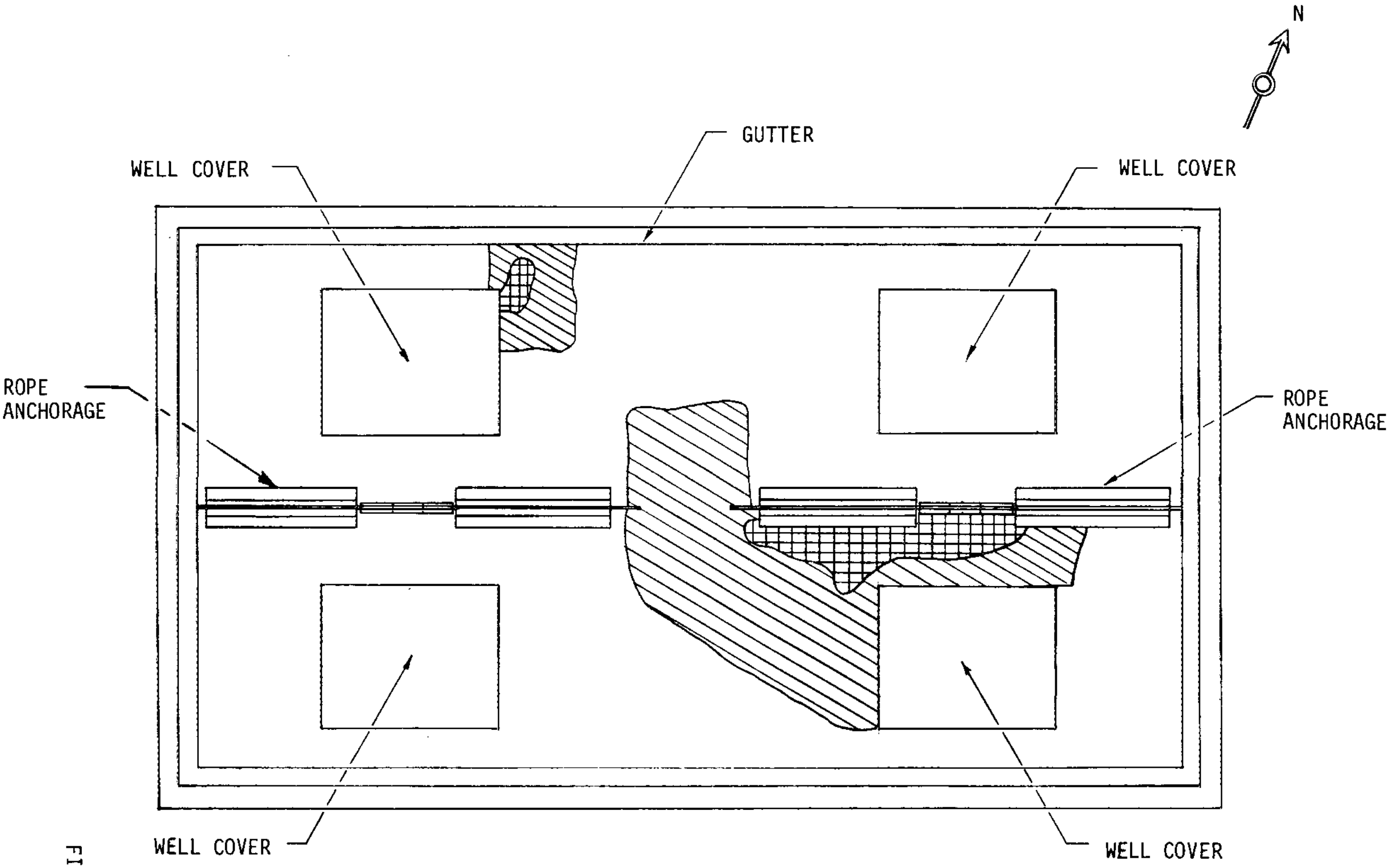
1. Repair the spalled and unsound concrete areas in the cap of the south main counterweight (approximately 59 square feet) and clean and seal the concrete surfaces at both main counterweights.

2. Clean and paint the undersides of the well covers of both main counterweights.

3. Replace deteriorated well cover fastener nuts for the south main counterweight at four anchor bolts.

4. Replace the deteriorated caulking around the hanger metalwork at each main counterweight.

5. Thoroughly clean and paint the hanger metalwork of both the main and auxiliary counterweights.



PLAN VIEW TOP OF SOUTH MAIN COUNTERWEIGHT

LEGEND

SPALLED CONCRETE

UNSOUND CONCRETE

SCALE: ¼" = 1'-0"

FIGURE 4-1

MODJESKI & MASTERS
ENGINEERS

Project VERTICAL LIFT RAILWAY BRIDGE
Subject SOUTH COUNTERWEIGHT
CONCRETE DETERIORATION

Made by MFB Date 6/19/84
Checked by KMK Date 7/20/84
Sheet No. 1 of 1

PART V-5

MECHANICAL EQUIPMENT

PART V-5 - MECHANICAL EQUIPMENT

Introduction

An in-depth inspection was made of the mechanical systems on the Buzzards Bay Bridge during the weeks of April 20, May 7, May 14 and June 4, 1984. During the inspection, measurements were taken on the gear teeth and bearing clearances were taken in each bearing possible in the drive systems. Span measurements were taken on all gears, except the racks attached to the counterweight sheaves. Chordal measurements were taken on the racks. The bevel gears in the differentials and equalizers are not accessible for measurement. They were checked visually.

Wherever possible, bearing clearances were taken with feeler gauges. When access to both ends of a bearing is blocked by a gear, coupling, shoulder or other hindrance, the bearing clearance was measured with a dial indicator. All measurements taken during the inspection are tabulated in tables at the end of the text.

The span drive bearings in split housings were opened for internal inspection. The bearing cap bolts and nuts on the lower span lock drives are so corroded that they could not be removed safely for fear that the bearings could not be reassembled. The bearings in the upper span locks and the rail locks are all in one piece housings that cannot be disassembled.

All motor couplings were opened for internal inspection. The inspection cover for the speed reducers in the lower span lock drive systems were removed to inspect the reducer gearing.

The pressure in each pair of buffer cylinders was checked by inserting pressure gauges between the valves and the cylinders.

The original intent was to open two of the counterweight trunnion bearings for internal inspection. Defects were found in both of the first two opened. Therefore, the remaining fourteen trunnion bearings were opened also.

A representative from the bearing manufacturer was present and did the actual inspection of the first two trunnion bearings opened. Steel flakes and slivers found in eight bearings were sent to the bearing manufacturer for their analysis. A copy of their report is included in Appendix B.

All of the main counterweight ropes and the auxiliary counterweight ropes were visually inspected. The sheaves, rope guides and rope sockets were also inspected.

Oil samples were taken from the two span lock speed reducers and the two rail lock gear motors. Grease samples were taken from the sixteen trunnion bearings. All of the lubricant samples were sent to a test laboratory for analysis. A copy of the report from the laboratory is included in Appendix B.

The plumbing in the control house was inspected by a local plumbing inspector. A copy of the inspector's report is included in Appendix B.

Colored photographs were taken of all conditions of interest observed. Mounted prints of the photographs can be found in Volume II of the report.

Observations and Discussion

Span Drives

The span drives are basically in good condition. The machinery operates smoothly with no unusual noises being created during operation. All parts in the machinery rooms were found to be well lubricated during the inspection.

The span drives have been altered somewhat since the original installation. There is an emergency motor drive provided in each tower to operate the span under reduced power and speed. Originally, there was a complete drive train from the emergency motor to the shaft and the first reduction pinion (P_5) used in the normal motor drive system. A clutch was provided to engage the emergency drive.

The emergency motor, motor coupling, and the first reduction pinion and shaft remain in place. The idler gear and shaft has been removed from each drive, but is available in each machinery room. The clutching mechanism that was to be used for engaging the emergency drive has been removed and apparently was discarded. The gear that operated with the clutch has been replaced with a gear that is keyed to the shaft that also has Pinion P_5 mounted on it.

The emergency motor drives can still be used. It would be necessary to reassemble the idler gear and shaft in the machinery frame in each tower to utilize the drives. If there was a problem with any of the motors and/or brakes used for normal operating, the motor coupling for the defective motor or brake may have to be disconnected before using the emergency drive.

The idler gear assemblies appear to be usable. The bearing journals are corroded. The journals should be polished, then protected from corrosion. Then, if they must be used, some time in the future, the journal will be ready for use without delay.

The span drive contains a clutched differential mechanism in the first reduction gear (G_3) assembly. The theory for using the differential at this location is to provide a quick method to level the end of the lift span during original construction, and to relevel the end of the span at any later date. Occasionally, unequal stretch of the counterweight ropes, slippage between the counterweight ropes and the sheaves, or some other unforeseen circumstances will cant the end of the lift span.

The normal method of operation would be as follows:

The differential clutch is engaged under normal operations. With the clutch engaged, the differential cannot operate as a differential. The two output shafts of the differential are locked together by the clutch. The two corners of the span then travel up and down at the same rate of speed, regardless of the vertical force required at each corner.

If, at any time, the span is lowered to the fully closed position and one live load shoe comes into contact with its support, but the second live load shoe does not come into contact, the differential clutch could be disengaged. The span drive could then be energized in the lowering direction to drive the corner of the span that is not in contact down until contact occurs. The differential clutch would then be reengaged.

The differential clutch is held in engagement by a counterweight that applies the necessary axial pressure between the engaging cones through a system of levers. To disengage the clutch, a GE Thrustor is energized to raise the counterweight, remove the pressure from the engaged cones and separate them slightly.

The clutched differentials should not operate as differentials during normal operations. When this occurs, the ends of the lift span have a great tendency to tilt. Any small difference in resistance to vertical movement in the two corners of one end of the span has an adverse effect on the drive system that tends to feed on itself. The corner of the span that has the greatest resistance to movement will slow down while the corner that has the least resistance will accelerate. This will tilt the end of the span. The tilting of the ends of the span may further increase the resistance to movement on the corner that already had excessive resistance, further aggravating the condition.

When the cone clutches in the clutched differential are solidly engaged, the tilting of the end of the span cannot occur. The two corners of the span raise at the same speed, even though the resistance to movement is not identical in the two corners.

The clutches on the Buzzards Bay Bridge have been locked in the disengaged position. The thrustors are no longer operable. Photograph 1 shows the Thrustor provided to operate the differential clutch on the North Span Drive. Note that the push rods emerging from the top of the cylinder have been painted. This paint will cause the rods to bind in their guides. The counterweights that should be applying the force to engage the clutch are being held in the raised position by a steel plate that has been bolted to the counterweight. The differential now operates as a differential.

All of the components of the cone clutches and the Thrustor that was provided to release the cone clutches are still in place. They have not been used for many years, and would have to be disassembled to check them thoroughly and be rehabilitated.

During the inspection, an attempt was made to operate both Thrustors. The Thrustor on the North Span Drive "hummed" when energized, but no movement was detected. The Thrustor on the South Span drive moved upward approximately 1/32 inch when energized.

The lack of movement of the Thrustors when energized may very well be because the counterweights are blocked in the fully raised position. The Thrustors may be operable, but after being unused for many years, they should be disassembled, completely inspected and the paint removed from the push rods, seals and guides. The Thrustors could then be tested and returned to service.

With the cone clutches disengaged, the drives cannot keep the ends of the lift span level. This function must now be done by the transverse span guides. Therefore, the forces on the transverse span guides required to withstand unequal lifting forces developed are added to the forces on the guides, produced by wind loads.

When the span is subjected to high transverse wind loads, the span tilts as it raises and lowers. When the span reaches the fully closed position, the live load shoes on one side of the span hit the strike plates first. The span drive continues to rotate driving the second side down until the live load shoes on that side also bottom. The bridge operators confirmed that this occurs.

On most bridges, the motor brakes are used to stop the movable span on lift bridges. The machinery brakes are for emergency purposes. The machinery brakes on the Buzzards Bay Bridge are being used to control the speed of the span during closing. The brakes are engaged when the lowering span is approximately ten feet above the fully closed position. Then the motors must drive the span down through two brakes that are set. If the brakes do not have identical torque settings, the span will tilt as it is being driven with the brakes set.

The fluid in the Thrustors has "never been changed" in the time that the present bridge operators have been working on the bridge. The pin connections on the brakes are not being lubricated. The fluid should be changed annually and a few drops of oil should be applied to each pin connection monthly.

There is only one limit switch mounted on each of the Span Drive brakes. The limit switch is tripped when the brake is released manually. Ideally, two more limit switches would be mounted on each brake. One would provide an indication when the brakes are released (either manually or electrically) and one would provide an indication when the brake is set.

North Span Drive

A machinery schematic for the North Span Drive is shown with Tables 1 through 3 at the end of the text. Bearing clearances measured are tabulated in Table 1. Gear tooth measurements taken are tabulated in Table 2. Conditions found for other components are contained in Table 3.

Bearings

The machinery bearings in this span drive train that could be inspected are all in acceptable condition. The bearings that could be measured had clearances of .001 inch to .019 inch. Apparent wear varies from "0" to .014 inch. This amount of wear is much less than average for a bridge that has been in service for fifty years. The bearings that were opened for internal inspection showed some signs of mild deterioration. The journal in Bearing B_{13} has light scratching as seen in Photograph 2. The bronze in the cap had one deep score mark, not visible in Photograph 3. Apparently, a piece of abrasive material found its way into the bearing at some time.

All of the bearings in the span drive that could be inspected are in acceptable condition. Assuming that all bearings have received the same care, it should be safe to say that the remaining bearings are also in acceptable condition.

Brakes

There are five thrustor type brakes on each span drive. Brake E, on the North Span Drive, is mounted on the Emergency Drive Motor and is not being used. The other four brakes are in service. No serious mechanical problems were found with the brakes. A few minor problems exist.

The limit switch on Brake A does not actuate. The outside diameter of the brake wheel is not well polished.

The outside diameter of the brake wheel on Brake E is rusty. The brake shoes must be readjusted before the brake can be used.

The lock nut on the brake shoe clearance adjustment is loose on Brake G. There are some old score marks on the outside diameter of the brake wheel. Photograph 4 shows the brake.

The limit switch doesn't actuate on Brake H. The outside diameter of the brake wheel has old score marks.

The Thrustors on the two motor brakes and the two machinery brakes all release their brakes in less than one second after they are energized. When the Thrustors are deenergized, the brakes set in a reasonable sequence that will not cause undue shock loads in the system. Brake A sets in 1-1/2 seconds, Brakes B, H and G set in 6 seconds.

Couplings

The three motor couplings in the span drive system are Falk, grid type, flexible couplings. The existing couplings are obsolete. They are in good condition.

This obsolete style of coupling has one problem that does not affect the utility, but can create a housekeeping problem. There are no seals provided in the coupling to prevent leakage of lubricant. If there is an excessive amount of lubricant in the coupling, the lubricant can leak out. The speed of rotation of the couplings is high enough to fling the lubricant quite a distance around the machinery room.

Some time in the past, canvas has been tied around each motor coupling. The canvas prevents lubricant from being thrown around the room, but it makes inspection and relubrication of the couplings more difficult.

The three couplings were opened for internal inspection. No defects were found. Coupling C_2 can be seen in Photograph 5.

Gears

The gears in the North Span Drive System are all in acceptable condition. Only minor wear has taken place and all gears were found to be well lubricated during the inspection. Lubrication of the racks (Gears R_1 through R_4) was marginal.

The maximum apparent wear found was a loss of .059 inch from the gear tooth thicknesses on Gear G_5. This represents a loss of 7.9% of the original thickness. The measurements of other gears can be found in Table 2 at the end of the text.

Gear alignment of Gearset P_5-G_5 is not good. The gear teeth have end loading as seen in Photograph 6. The misalignment is caused by the axial loading on the rim of the gear due to the helical gear tooth reaction. Herringbone, or double helical gears, would be better for this application. The reduced area in contact undoubtedly contributed to the more rapid wear for G_5 than for other gears in the system. However, the wear is still minor and will not reduce the utility of the gear.

Photograph 7 shows Gearset P_5-G_5 after some of the teeth were cleaned off for inspection. The teeth are in good condition.

The equalizer gears at both ends of the span drive are in good condition. Gearset P_3-G_3 in the east equalizer is shown in Photograph 8.

The Pinions P_1B and P_1C are nearly inaccessible. It was necessary to squeeze through a narrow opening alongside the counterweight rope to get into a constricted space to measure the pinions (see Photograph 9).

The gearing driving the limit switches and skew transmitter are also in good condition. The crossed helical gears seen in Photograph 10 provide the drive for the skew transmitter. Crossed helical gears have only point contact and the gear tooth surfaces have scuff marks, even though lightly loaded and well lubricated.

The spur gearset seen in Photograph 11 drives the skew limit switch. The limit switch and skew transmitter can be seen in the photograph. The gearset is in good condition.

Shafts

The shafts in the power train for the North Span Drive were inspected. Special attention was given to the areas including stress risers, such as shoulders and keyways. No distress was found. The shafts are well painted. No corrosion problems exist.

South Span Drive

A machinery schematic for the South Span Drive is shown with Tables 4 through 6, at the end of the text. Bearing clearances measured are tabulated in Table 4. Gear tooth measurements taken are tabulated in Table 5. Conditions found for other components are contained in Table 6.

The condition of the South Span Drive is much the same as the condition of the North Span Drive. There is no unusual noise generated during operation of the drive machinery. All parts were well lubricated. Apparent wear for the bearings and gears are all within acceptable limits.

Bearings

The machinery bearings in this span drive train that could be inspected are all in acceptable condition. The bearings that could be measured had clearances of "0" to .016 inch. Apparent wear varies from "0" to .010 inch. This amount of wear is much less than average for a bridge that has been in service for fifty years. The bearings that were opened for internal inspection showed some signs of mild deterioration. The journal in Bearing B_9 has minor scoring and only 35% contact, as seen in Photograph 19.

Bearing B_{10} has minor scratching and 60% contact. Bearing B_{13} is well aligned with virtually 100% contact, as seen in Photograph 12. The journal for B_{13} is seen in Photograph 13.

Bearing B_{14} is poorly aligned with its shaft, as seen in Photograph 14. There is only about 10% contact between the shaft and cap. Some of the old, hard grease was scraped out before the photograph was taken. There is minor scoring on the journal, as seen in Photograph 15.

Bearing B_{15} is also poorly aligned with the shaft. Contact in the cap is approximately 10%, as seen in Photograph 16. Note that the bronze is dull, not polished in the cap. The bearing journal has minor scratching, as seen in Photograph 17.

Bearing B_{16} has approximately 25% contact as seen in Photograph 18. The journal has minor scratching.

Although the majority of bearings are poorly aligned with their shafts, wear has been minimal. The condition does not warrant reworking the machinery frames that the bearings are mounted in to correct the misalignments.

All of the bearings in the span drive that could be inspected are in acceptable condition. Assuming that all bearings have received the same care, it should be safe to assume that the remaining bearings are also in acceptable condition.

Brakes

There are five thrustor type brakes on the South Span Drive. Brake F is mounted on the Emergency Drive Motor and is not being used. The other four brakes are in service. No serious mechanical problems were found with the brakes. A few minor problems exist.

The limit switches on Brakes C and D do not actuate. The outside diameter of the brake wheel on Brake D is not well polished, but is smooth. No signs of distress.

The outside diameter of the brake wheel on Brake F is rusty. The brake shoes should be replaced before the brake is used. The brake has no limit switch.

The limit switch is inoperable on Brake J. The outside diameter of the brake wheel is well polished, as seen in Photograph 20.

The limit switch moves, but apparently doesn't trip on Brake K. The outside diameter of the brake wheel is nicely polished.

The Thrustors on the two motor brakes and the two machinery brakes all release their brakes in less than one second after they are energized. When the Thrustors are deenergized, the brakes set in a reasonable sequence that will not cause undue shock loads in the system. Brake C sets in 1-1/2 seconds, Brake D sets in 2-1/2 seconds, and Brakes J and K set in 4 seconds.

Couplings

The three motor couplings in the span drive system are the same Falk, grid type, flexible couplings found on the North Span Drive. They are in good condition. The three couplings were opened for internal inspection. No defects were found. Coupling C_3 can be seen in Photograph 21. This photograph is representative of all three couplings. Coupling C_1 needs to be relubricated.

Gears

The gears in the South Span Drive system are all in acceptable condition. Only minor wear and a few nicks were found. All gears were found to be well lubricated during the inspection. Lubrication of the racks (Gears R_1 through R_4) was marginal.

The maximum apparent wear found was a loss of .062 inch from the gear tooth thicknesses on Gear G_5. This represents a loss of 8.3% of the original thickness. The measurements of other gears can be found in Table 5 at the end of the text.

Gear alignment of Gearset P_5-G_5 is not good. The gear teeth have the same type of end loading as the same gearset in the North Span Drive. The same helical gear tooth reaction caused the condition and the reduced area in contact contributed to the more rapid wear for G_5 than for other gears in the system. However, the wear is still minor and will not reduce the utility of the gear. Photograph 22 shows the minor wear on Pinion P_5. The teeth are in good condition.

Photograph 23 shows the bevel gears in the clutched differential. If the clutch was properly engaged, the bevel gears could not rotate. The bevel gear teeth in the photograph are clean, indicating that they have been in contact recently.

The equalizer gears at both ends of the span drive are in good condition. Gearset P_3-G_3 in the west equalizer is shown in Photograph 24. This gearset was misaligned, but was worn in to produce full face contact. Pinion P_{1D} and Rack R_4 are axially misaligned 7/8 inch. Pinion P_{1D}, seen in Photograph 25, is in good condition. This photograph is representative of all of the rack pinions on the bridge.

Lower Span Locks

Measurements taken for the components in the span lock system can be found in Tables 7 and 8 at the end of the text. The nomenclature used in the following descriptions can be found on the schematic drawing used with the tables.

North Pier

No unusual noises were heard during operation of the span lock machinery.

The mounting brackets for the solenoid brake on the span lock drive are heavily corroded, as seen in Photograph 26. The shoes are not in firm contact with the brake wheel when the brake is set. The flange bolts on the motor coupling were moderately corroded.

The grid in the motor coupling was found to have several fractures when the coupling was opened for inspection. The coupling had no lubricant and all internal parts were heavily corroded, as seen in Photograph 27. The fractured grid was replaced and the coupling cleaned and lubricated before our inspection was completed.

The oil in the span lock reducer was heavily contaminated. Sludge from the bottom of the speed reducer can be seen in Photograph 28. The oil collecting grooves above the bearings were also full of sludge.

The test results from Ana Labs do not support our visual findings completely. Before taking oil samples, the span lock machinery was operated through several cycles. However, the thick sludge at the bottom of the reducer housing apparently did not become dispersed. Therefore, the results of the tests are not valid. The lab found wear metals in the oil "mildly above normal" and contaminants "acceptable".

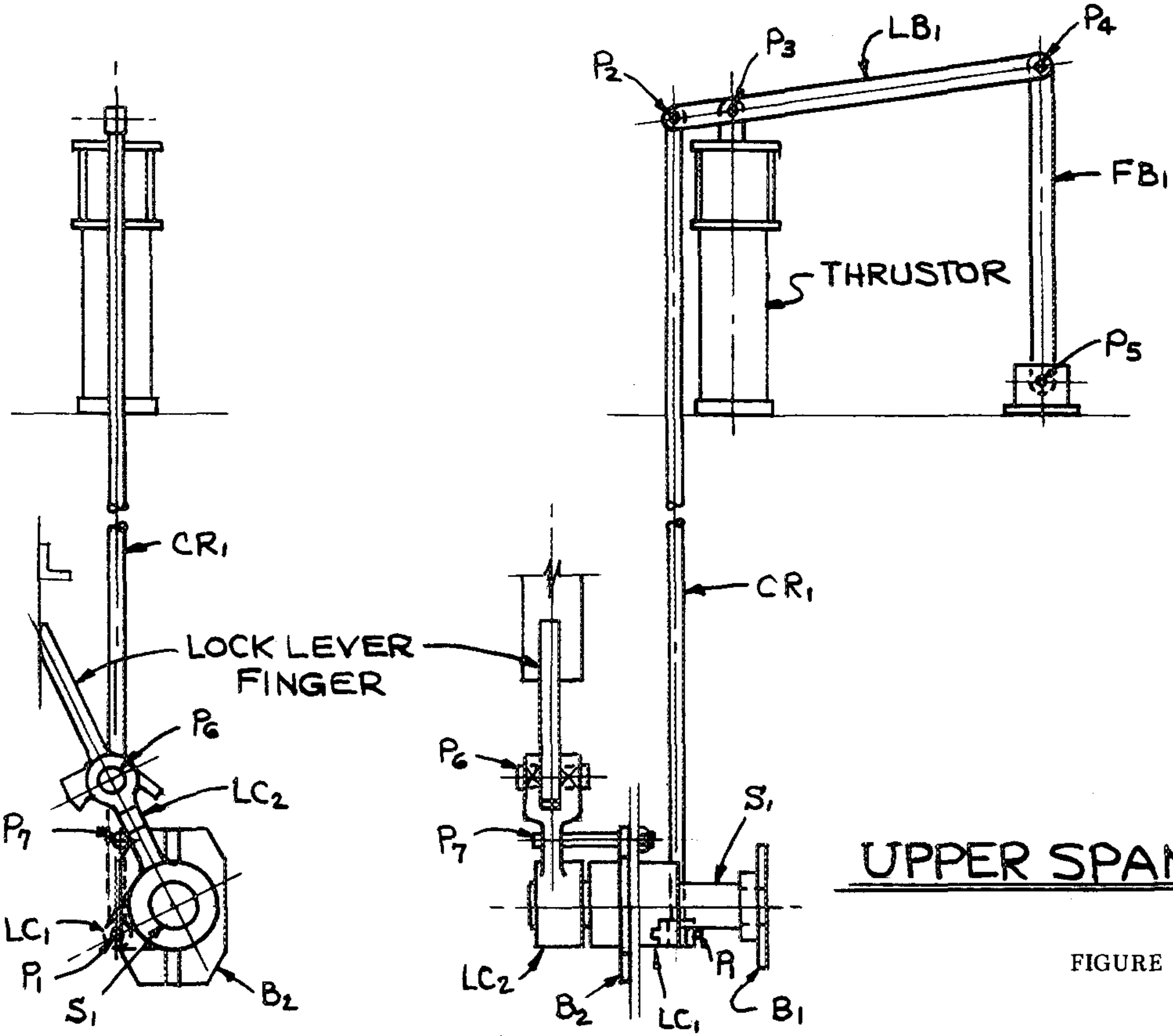
The nuts on the reducer base plate anchor bolts in the northwest and southwest corners of the reducer are heavily corroded, as seen in Photograph 29. One of the bearing bolts on the south side of the reducer housing is heavily corroded, as seen in Photograph 30.

The nuts on the cap bolts for Bearing B_2 are heavily corroded. The southeast cap bolt is also corroded.

The Pinion PG_1 and Sector Gear SG_1 transmit power from the output shaft of the speed reducer to a jack shaft journaled in Bearings B_2 and B_3. SG_1 is mounted on one end and Lever CL_1 is mounted on the opposite end of the jack shaft.

Gearset PG_1-SG_1 had not been lubricated for many years. Recently, the operators began lubricating the gearset. The heavy loss of metal on the Pinion PG_1, due to corrosion, can be seen in Photograph 31. The gear teeth at the end of Section Gear SG_1 can be seen in Photograph 32.

The connecting rods (Parts L_1 and L_2) are made up of pipe with a clevis bolted to each end. The bolts and nuts are heavily corroded in virtually every location, as seen in Photographs 33 and 34.



UPPER SPAN LOCK

FIGURE 1

The west lock bar pocket, mounted on the pier has light corrosion. The anchor bolts for both pockets have light corrosion. One nut is missing on an anchor bolt on the east pocket and two are missing on the west pocket.

South Pier

The Lower Span Lock Machinery on the South Pier is basically in the same condition as that on the North Pier. The motor mounting bracket is heavily corroded. The open gearset teeth had lost a great deal of section through corrosion before they were included in the regular lubrication procedure. Many of the nuts on the bearing cap bolts, the connecting rod assembly bolts and nuts, and the lock bar socket foundation bolts are heavily corroded.

Photograph 35 shows some of the gear tooth corrosion on Gear SG_1 and corroded cap bolt nuts on Bearing B_2. Photographs 36 and 37 show corroded assembly bolts on the connecting rods.

When the motor coupling was opened for internal inspection, the coupling was found to have no lubricant inside. All internal parts were corroded. There was no guard over the coupling.

The lock bar socket and the live load supports at the south end of the bridge are in close proximity to one another. Debris has collected in the spaces between them also. Water now becomes trapped between the parts and is accelerating corrosion of the parts and their anchor bolts and nuts.

Upper Span Locks

A schematic of the Upper Span Locks is shown in Figure 1. There are four sets of Upper Span Lock Machinery, one on each side of the span at each end. The Upper Span Locks have not been used for more than twelve years. All of the components are still in place, except the Lock Lever Fingers.

The Thrustors that were furnished to disengage the Upper Locks are still wired into the control circuits. The Thrustors go through each cycle when the span is being lowered. The Thrustors in all four Upper Span Locks release in two seconds and retract in two seconds. The Thrustors and Levers FB_1 and LB_1 and the top end of Connecting Rod CR_1 are located in enclosures outside of the machinery rooms, as seen in Photograph 38. CR_1 has been disconnected from LB_1 in each of the systems, as seen in the photograph.

The bottom 75% of CR_1 is enclosed in the structural steel column in the corner of the tower. The inside surfaces of the column and CR_1 were not well painted, as seen in Photograph 39. CR_1 is now lightly corroded.

Lever LC_2 has a clevis at the top end that formerly held the Lock Lever Finger. Lever LC_2, as seen in Photograph 40, is the arrangement used at the fixed end of the span. The arrangement seen in Photograph 41 is used at the expansion end. Bearings B_1 and B_2 support the shafts on which

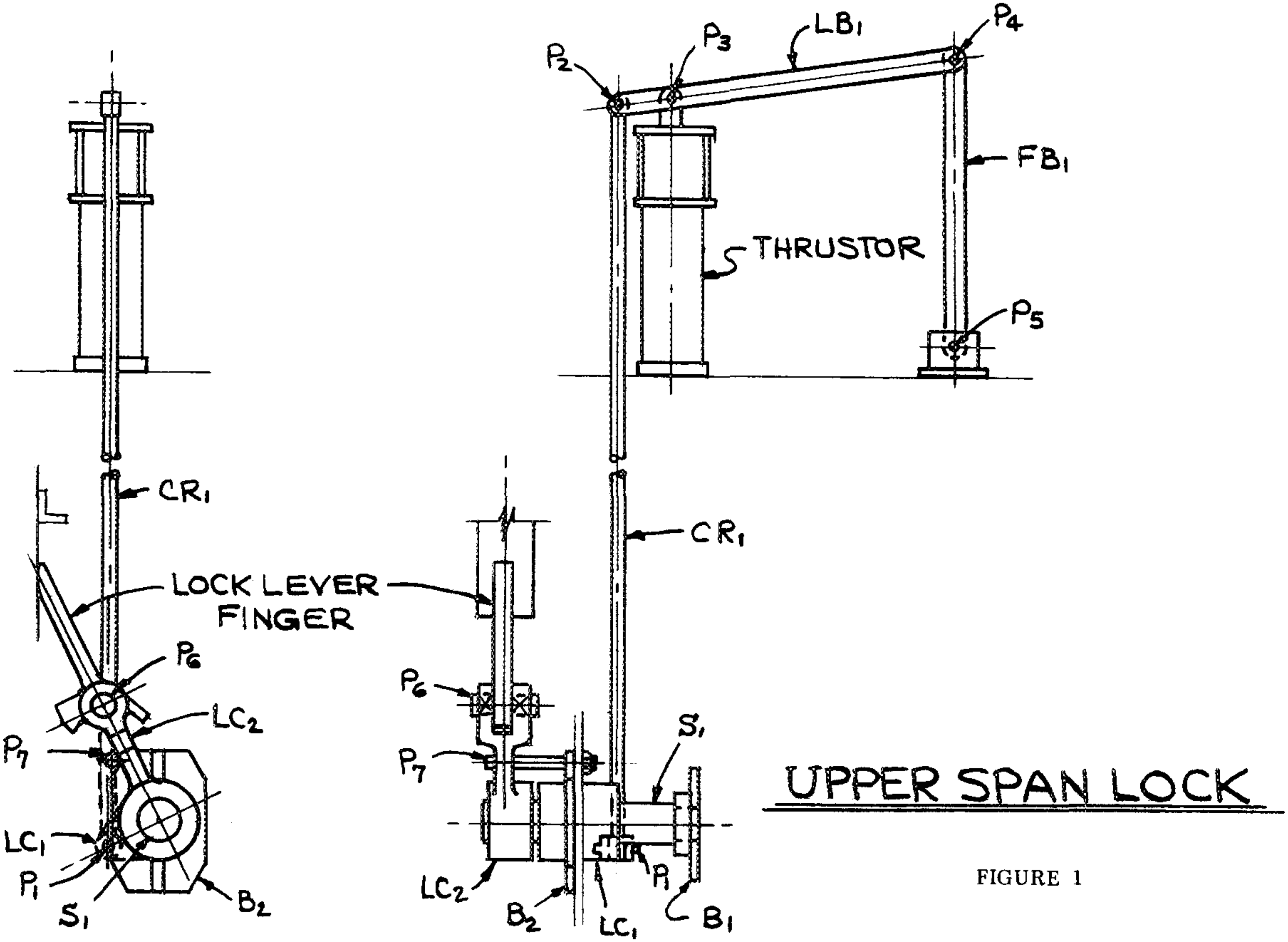

LB1
P2
P3
P4
FB1
THRUSTOR
P5
CR1
CR1
LOCK LEVER
FINGER
P6
LC2
P7
P6
P7
S1
LC1
P1
S1
B2
LC2
B2
LC1
P1
B1
UPPER SPAN LOCK

FIGURE 1

LC_2 is mounted. B_1 is located inside the column. B_2 is mounted on the column side plate, as seen in the photographs. The nuts on the mounting bolts for B_2 are moderately corroded in several locations.

Rail Locks

North End of Span

A schematic of the Rail Lock Machinery can be seen in Figure 1a.

The brake for the Rail Lock drive is a motor mounted solenoid brake. The west shoe does not retract when released. No other mechanical problems were found with the brake.

No unusual noises were heard when the Rail Lock machinery operated. The gear motor used in this drive has no inspection opening. Internal inspection cannot be made while it is mounted on the bridge.

An oil sample was taken from the gear motor used in this drive. The drive was operated through several cycles before the sample was taken. "Mildly above normal" wear elements were found in the oil. Contaminants found were within acceptable levels. However, our experience with the span lock reducers would make the test results questionable.

None of the bearings supporting gear shafts in the Rail Lock drives are accessible for measuring clearance with feeler gauges. No unusual radial shaft movements were observed in the bearings. Bearing B_1 is a flanged bearing mounted to the web of a transverse girder on the approach span. Four mounting bolts are used to mount the bearing. Three of the four nuts on the mounting bolts are heavily corroded, as seen in Photograph 43.

A "slip coupling" is used in the Rail Lock drive to prevent damage if parts are misaligned when the locks are driven. The coupling has a sheet metal cover that was removed before Photograph 42 was taken.

The sheet metal cover and the internal components seen in the photograph are all lightly corroded. No clutch lining debris was found inside the cover.

The Rail Lock drive utilizes a wide bronze spur pinion, Part PG_1, that drives Segment Gear SG_1 and the gears used to drive the limit switch, as seen in Photographs 43 and 44. Only a small percentage of the face width of PG_1 is used. The relatively soft bronze has deformed and worn considerably in the narrow band being used, as seen in the photographs. The gears in this part of the drive are not being lubricated.

Shaft S_2 is a non-rotating shaft that supports combination Segment Gear-Lever SG_1. The shaft is mounted with brackets that are bolted to the structural steel. The brackets are heavily corroded as are the mounting bolts.

The limit switch drive for the Rail Lock drive is heavily corroded. Approximately 50% loss of section has been experienced, as seen in Photograph 45.

South End of Span

The machinery in the Rail Lock drive system at the south end of the bridge is in the same condition as that on the north end. The bronze Gear PG_1 has the same type of wear as seen in Photographs 43 and 44.

The slip coupling is more heavily corroded on the south Rail Locks, as seen in Photograph 46. Note that the springs, studs and end plate are especially heavily corroded. No clutch lining debris was found in the cover to indicate unusual wear.

Buffer Cylinders

There are eight buffer cylinders on the Buzzards Bay Bridge. Four of the buffers are located on the bottom chords at each corner of the span. The other four buffers are located near the tops of the towers, two on each tower.

The four lower buffers mounted on the lift span were provided to cushion the span as it is approaching the fully closed position. The four upper buffers mounted on the towers were provided to cushion shocks when the span is approaching the fully open position.

Pressure gauges were insulated on each pair of buffer cylinders during the inspection, as shown in Photograph 47. Pressure buildup was monitored visually when the span approached the end of travel, pushing the buffer piston assembly up into the cylinder. Each buffer was also observed as the span moved, so as to allow the pistons to descend in the cylinder. Clearance measurements were taken around the piston rod guides at the bottom of each buffer.

The bridge operators indicated that they are lubricating the buffer cylinders, internally, by adding 1/2 gallon of #10 oil to the top of the cylinder twice a year. This is not frequent enough. The oil drains off from the sliding surfaces and the sliding surfaces wear and corrode if not coated more frequently. Adding a pint of oil monthly would provide better lubrication and corrosion resistance.

The buffer cylinders and their assembly and mounting bolts have not been well painted, as seen in Photograph 48. In the areas that are out of sight and/or difficult to reach, the surfaces have not been painted. As a result, the parts are corroding, especially the fasteners.

The piston rod assemblies descend by gravity. If the sliding surfaces are well lubricated and well polished, the piston assemblies descend smoothly. If the surfaces are not well polished and lubricated, the piston rod assemblies may descend in a jerky manner or not at all.

When the span was moving down away from the upper buffers, the piston assemblies hung up in the two buffers on the north tower, indicating that the interior surfaces of the cylinder, the piston, and/or the piston rings may be corroded. The surfaces may not have sufficient lubricant, also. The piston assemblies in all other buffers descended smoothly.

The clearances in the guide bushings for the two buffers that hung up were checked. The bushings were well lubricated and there were clearances between bushings and the piston rods of .019 inch in the east buffer and .024 inch in the west buffer. Three of the assembly bolts for the west buffer were found to be heavily corroded.

The pressure regulator valve of the buffer cylinder on the north tower was set at the maximum open position. No pressure of any consequence can be built up with the valve fully opened.

The upper buffer cylinders attached to the south tower have clearances of .022 inch in the guide bushing for the east buffer and .018 inch on the west buffer. Clearances and lubrication of both bushings were acceptable. Four of the eight assembly bolts that hold the piston rod guide to the bottom of the west buffer are severely corroded. The nuts on the mounting bolts for this buffer are also heavily corroded. The pipe nipples between the buffer cylinder and the check valve and between the buffer cylinder and the pressure regulating valve have rusted completely through, as seen in Photographs 49 and 50. No pressure can build up in the cylinder. The nuts on the mounting bolts for the east buffer attached to the south tower are moderately corroded.

The nuts on the mounting bolts on the two lower buffers attached to the north end of the lift span are moderately to heavily corroded. The handles on the pressure regulating valves were both paint tight. Neither could be rotated to check the adjustment. During closing of the span, the pressure buildup in the two buffers was 5 psi in the east buffer and 3 psi in the west.

The nuts on the mounting bolts for the two lower buffers attached to the south end of the span are also corroded. The handle for the pressure regulating valve on the west buffer is missing and the valve stem is bent. The pressure buildup in the two buffers was 2 psi in each.

At the present time, the two motor brakes are being set when the span is approximately ten feet above the fully closed position. This is being done to prevent the span from seating at too great a speed. The buffer cylinders are not now doing their job. If they are properly sized and working correctly, the buffers would provide the cushioning effect required to prevent shock loads from occurring during closing.

Chain Hoists

There are four chain hoists in service on the Buzzards Bay Bridge. There is a five ton hoist over the machinery room in each tower, a 1/2 ton hoist in the auxiliary generator house and a three ton hoist over the railroad tracks outside the operators house. The four hoists were included in this inspection.

All of the hoists are in good operating condition. The 1/2 ton hoist in the generator house is like new, as seen in Photograph 51. The three ton hoist over the tracks is kept in an enclosure outside of the operators house. The hoist has light corrosion on the various components, as seen in Photograph 52.

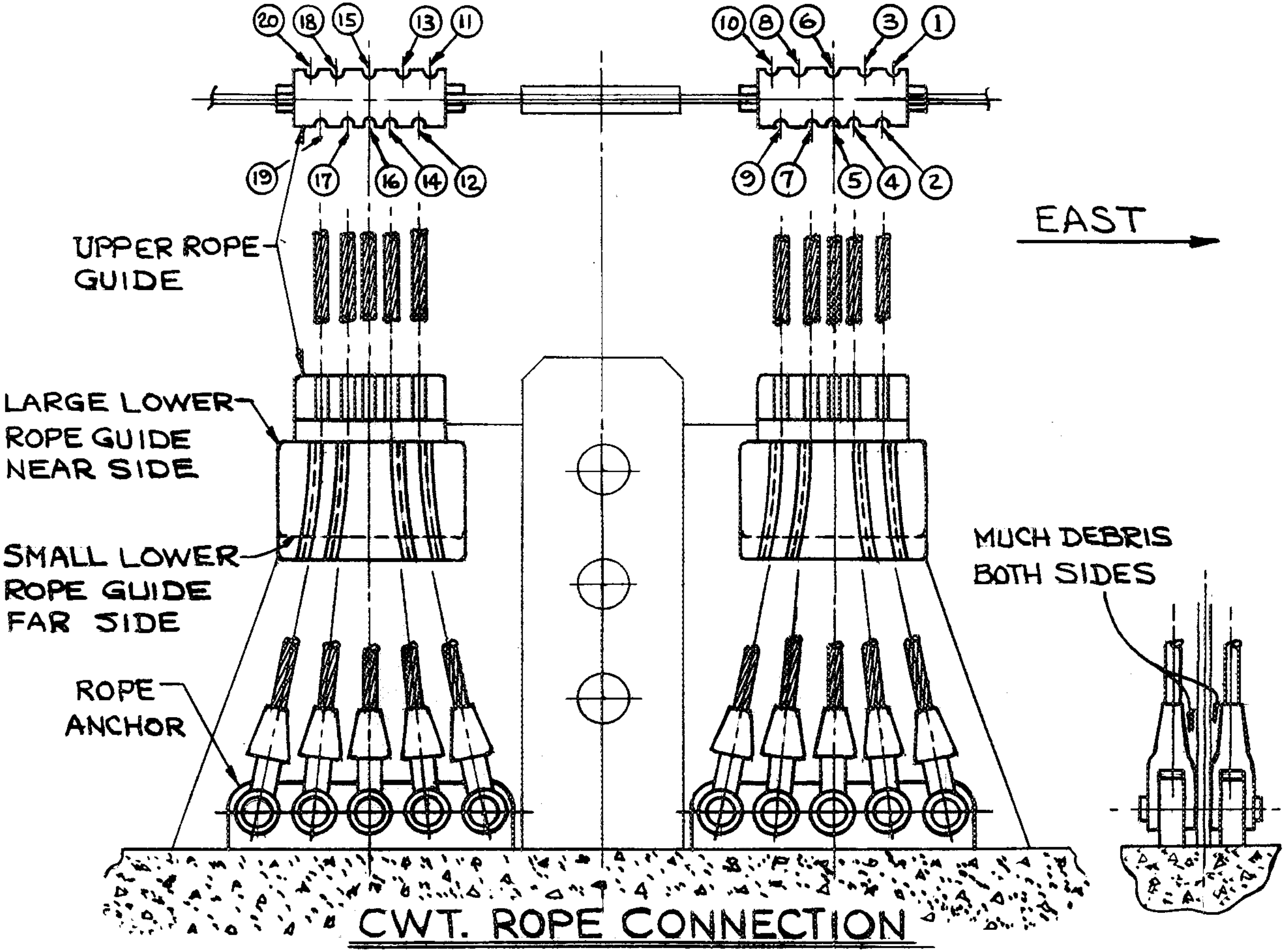

20
18
15
13
11
10
8
6
3
1
19
17
16
14
12
9
7
5
4
2
EAST
UPPER ROPE GUIDE
LARGE LOWER ROPE GUIDE NEAR SIDE
SMALL LOWER ROPE GUIDE FAR SIDE
MUCH DEBRIS BOTH SIDES
ROPE ANCHOR
CWT. ROPE CONNECTION

FIGURE 2

The five ton hoist in the north machinery room is in good operating condition. Paint is peeling from one side of the beam the hoist trolley is mounted on, as seen in Photograph 53. The paint is in good condition on the opposite side of the same beam, as seen in Photograph 54. The chain is lightly corroded, but other components of the hoist are in good condition, as seen in the photographs.

The gearing used in the traversing drive can be seen in Photograph 55. Light rust is evident on the gears and on the outside diameter of the wheel in the photograph, but no serious problems were uncovered. The entire truck at both ends is well painted and in good condition, as seen in Photographs 56 and 57. The track that extends behind the elevator is lightly corroded and has scattered paint and debris on the rolling surface, as seen in Photograph 58. Other parts of both tracks are in similar condition.

The five ton hoist in the south machinery room is also in good condition. The photographs shown for the hoist in the north machinery room are typical of the conditions found in both hoists.

Main Counterweight Ropes

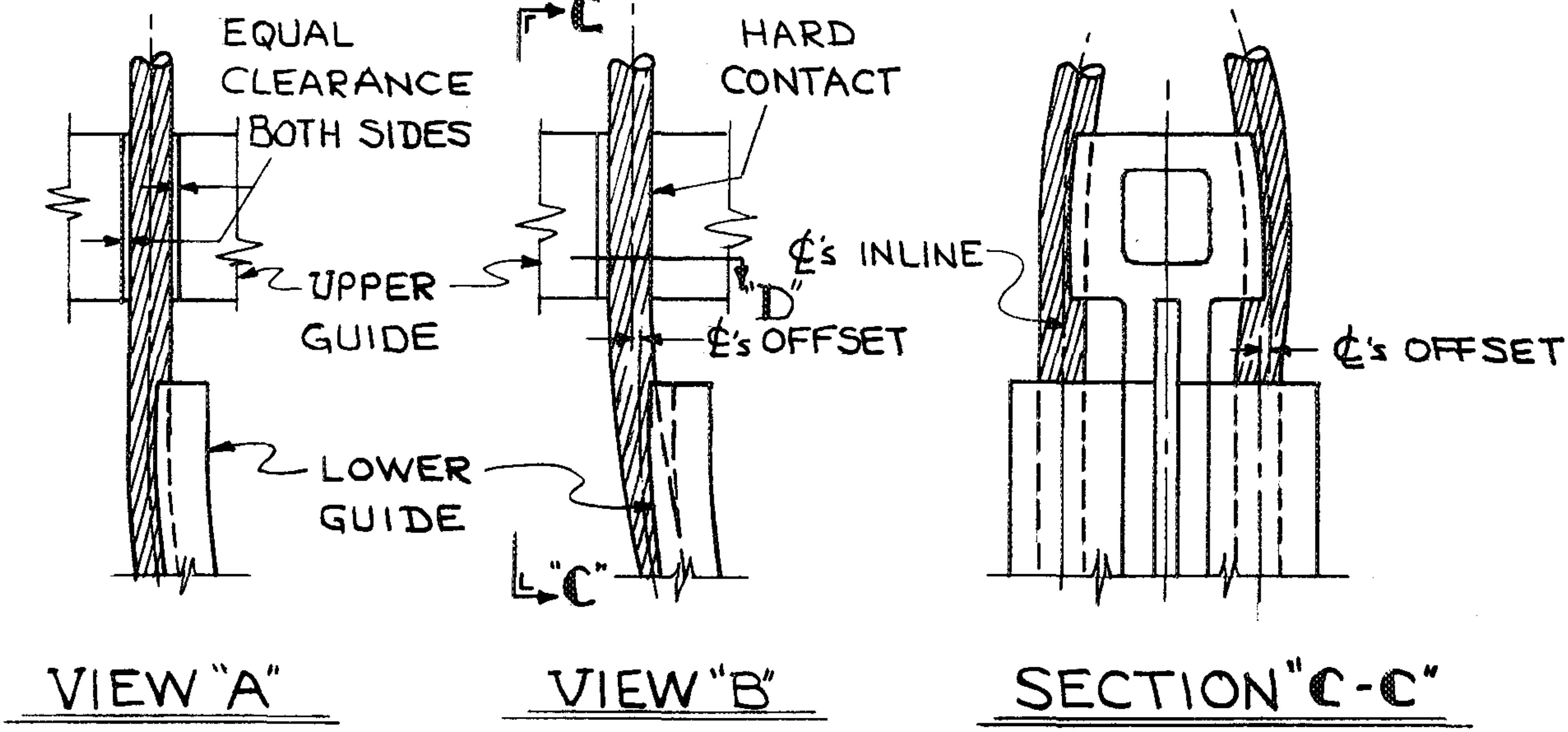
The counterweight ropes have serious deficiencies. The ropes are damaged at the guides that separate the ropes atop the counterweights. The lubrication of the ropes is poor. Much corrosion is in evidence on the ropes. When the lubricant on the ropes was scraped off, water ran out of the ropes in many places.

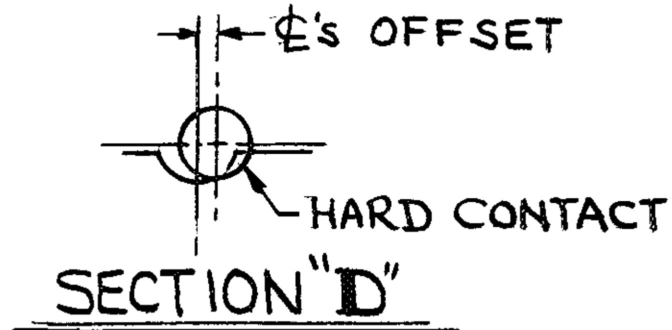
There are forty ropes connecting the lift span to the counterweight at each end of the span. For purposes of clarity, the ropes were numbered from 1 to 40 at each end of the span, with #1 being the most easterly rope then numbered consecutively. Ropes 1 and 10 pass over the most easterly sheave and are attached to the counterweight in one group. Ropes 11 through 20 pass over the sheave second from the east and are attached to the counterweight in a second group, etc.

Each group of ten ropes comes off from one side of a sheave in the same vertical plane. The ten ropes then extend down from one side of the sheave and are attached to the lift span and extend down the opposite side of the sheave and are attached to the counterweight. The 2-1/4 inch diameter ropes leave the sheave on 2-1/2 inch centers. The wire rope sockets and pin connections required to equal the strength of the rope are 10 inches across. Therefore, the ropes must be spread apart substantially to make room for the connections.

When the ten ropes approach the counterweight, they are first divided into two groups of five ropes by the "Upper Rope Guide", as seen in Figure 2. Five ropes pass on each side of a vertical steel plate. Each group of five ropes are then spread apart by the lower rope guide, also seen in the schematic.

There are curved rope grooves in both the upper guides and the lower guides to give support to the ropes as they are being deflected.





SECTIONS THRU ROPE GUIDES

FIGURE 3

Theoretically, the spacing of the rope groove at the bottom of the upper guide is exactly the same as the spacing between the rope grooves at the top of the lower guide. Then, if the guides are properly aligned, each rope would pass from the upper guide groove to the lower guide groove with no side pressure on the rope.

Unfortunately, the grooves in the upper rope guides do not have the same spacing, nor are they properly aligned with the grooves in the lower rope guides, as shown in Figure 3.

Figure 3, View A, shows the centerlines of the grooves properly in line with one another in a north-south plane. View B shows centerlines of the grooves offset from one another. In Section C, the grooves on the left side of the guides are in line in an east-west plane, while those on the right side are offset.

Counterweight Ropes 2, 4, 6, 7 and 9 on the North Counterweight are seen in Photographs 59 and 60. Note in Photograph 60 that four ropes are pushed to one side of the grooves in the upper guide. This is because of misalignment between the grooves in the upper and lower guides. The ropes are pressed hard against the sharp corner of the groove. In this group of ten ropes, Ropes 2, 4, 5, 7 and 9 are pressed hard against the sides of the grooves and show fretting corrosion. The other five ropes also are pressed against the sides of the grooves, but less severely.

The counterweight ropes vibrate whenever the wind blows at the bridge site, almost continuously. The vibrating ropes cause the ropes to pound against the upper rope guides. Where the ropes are pressed hard against the side of the groove and the sharp edge of the groove, the ropes are damaged, some severely. The constant pounding causes fretting corrosion of the ropes and the guides. Iron oxide deposits are evidenced on many ropes. Note the heavy oxide deposits below the guides on the ropes in Photographs 59, 60 and 61.

Tags labeling each counterweight rope were apparently attached to each counterweight rope when they were shipped to the job site. The wires that held the tags were not removed from many of the counterweight ropes. Note also in Photograph 61 that three tag wires were left on one rope (#4) in the area where the rope is pressed against the rope groove. The tag wires probably have damaged the wires in the wire rope. This has occurred on other ropes also.

Photograph 62 illustrates how the counterweight ropes are attached to the counterweight. Ropes 1 through 20 are shown at the north counterweight. Note the iron oxide running down several of the ropes below the guides. Also note the corrosion between the steel plates at the near end of the attachment. There is a space between the steel plates. The spaces at every location are full of debris. Moisture held by the debris promotes corrosion of the plates, the rope sockets, the pins and the assembly bolts.

Photograph 63 shows Ropes 2, 4, 6, 7 and 9 at the south counterweight. Iron oxide can be seen below the guide in this photograph. Photograph 64 shows the east counterweight ropes at the south end of the span. Iron oxide can be seen between the ropes and the grooves.

Many of the ropes are damaged severely at the counterweight guides. The damage shown to the rope in Photograph 65 is typical. This type of damage is most severe at the south counterweight.

The ropes that are pressed hard against the edges of the grooves were each pushed out of the grooves with a hydraulic jack a short distance. The damage to the wires could then be seen reasonably well. Twenty-nine of the forty ropes at the south counterweight were found to be damaged. Rope 5 has five worn wires in each of four strands. Three strands each have seven damaged wires in a row in Rope 6. The fourth strand has four damaged and three broken wires. Four wires in each of four strands of Rope 7 are badly damaged. Nine wires in each of four strands have 50% loss of section in Rope 9. Ropes 15, 16, 17, 18, 21, 23, 24, 25, 26, 27, 28 and 30 through 40 are all damaged. The damage to the ropes at the north counterweight is also substantial, but less than that at the south counterweight.

The same basic rope guide arrangement is used for connecting the counterweight ropes to the span as is used at the counterweight. Since the span is held in the fully opened position the great majority of the time, the counterweight rope section between the span connections and the sheaves are short. When the lift span is in the full open position, the amplitude of vibration of the ropes above the guides at the span connections is much less than above the counterweight connections. Therefore, the damage to the ropes at the span connections is not as severe as at the counterweight. The ropes are damaged at the span end of the ropes, but not as severely.

The counterweight ropes are also suffering from corrosion. The ropes have been lubricated with Vitalife #5 rope dressing. This is not a good lubricant to be used for field dressing. The material is heated then applied by brush. As soon as it hits the cold ropes, it becomes very viscous and does not penetrate the rope.

Photograph 66 shows a typical section of Ropes 31 through 40 on the north end of the span. Note the ropes on the right in the photograph. The lubricant forms a solid cylinder. The lubricant does not extend into the valleys in many areas. Note the spots where the lubricant has pulled out of the valleys. There is space behind the lubricant and water can flow into the space where the lubricant has pulled away. The water then follows the valleys down the rope, soaks into the core and corrodes the rope.

Photograph 67 is a closeup of heavy corrosion in a valley of Rope 1, North Counterweight. Photograph 68 is a closeup of corrosion in Rope 9, North Counterweight. Photograph 69 shows Rope 3, North Counterweight. Photograph 70 shows Rope 8, North Counterweight. Photograph 71, 72, 73, 74 and 75 show corroded spots on other ropes on the North Counterweight. Photographs 76 and 77 show similar conditions on ropes on the South Counterweight.

Virtually every rope has corrosion in the valleys. The corrosion and lack of lubricant in the valleys has undoubtedly caused substantial loss of section in the wires that rub against each other as the ropes flex to pass over the sheaves. The corrosion observed was both oxidation type and fretting corrosion.

The amount of damage to the wires due to internal corrosion and rubbing cannot be determined while the ropes are in service. A rope that is known to have internal corrosion must be assumed to be a dangerous rope.

No record was found to indicate that a bench mark was made on the towers when the existing counterweight ropes were installed to allow measurement of stretch of the ropes. The only possible method to approximate stretch that the personnel at the bridge were aware of was a painted band on the North Tower. By unverified "word of mouth", the present operators were told that the lower counterweight guide originally stopped in the center of the painted band when the lift span was in full open position. The guide now stops 22 inches below the original level.

Several of the bolts and nuts that hold the upper rope guides to the span are heavily corroded. The bolts and nuts are in inaccessible locations. There were eight nuts found at the south end of the span that were heavily corroded and six at the north end.

The load distribution between the forty ropes at each end of the span is not good. The relative tension was checked by timing 30 vibrations of each rope on the counterweight side of the sheaves with the lift span in the full open position. The times are tabulated in Table 9 for the North Counterweight ropes, and Table 10 for the South Counterweight ropes.

The time interval for 30 vibrations varies from 17 seconds to 21 seconds at the North Counterweight or 23.5%. Since the tension varies as the square of the frequency of vibration, the tension varies 52.5%.

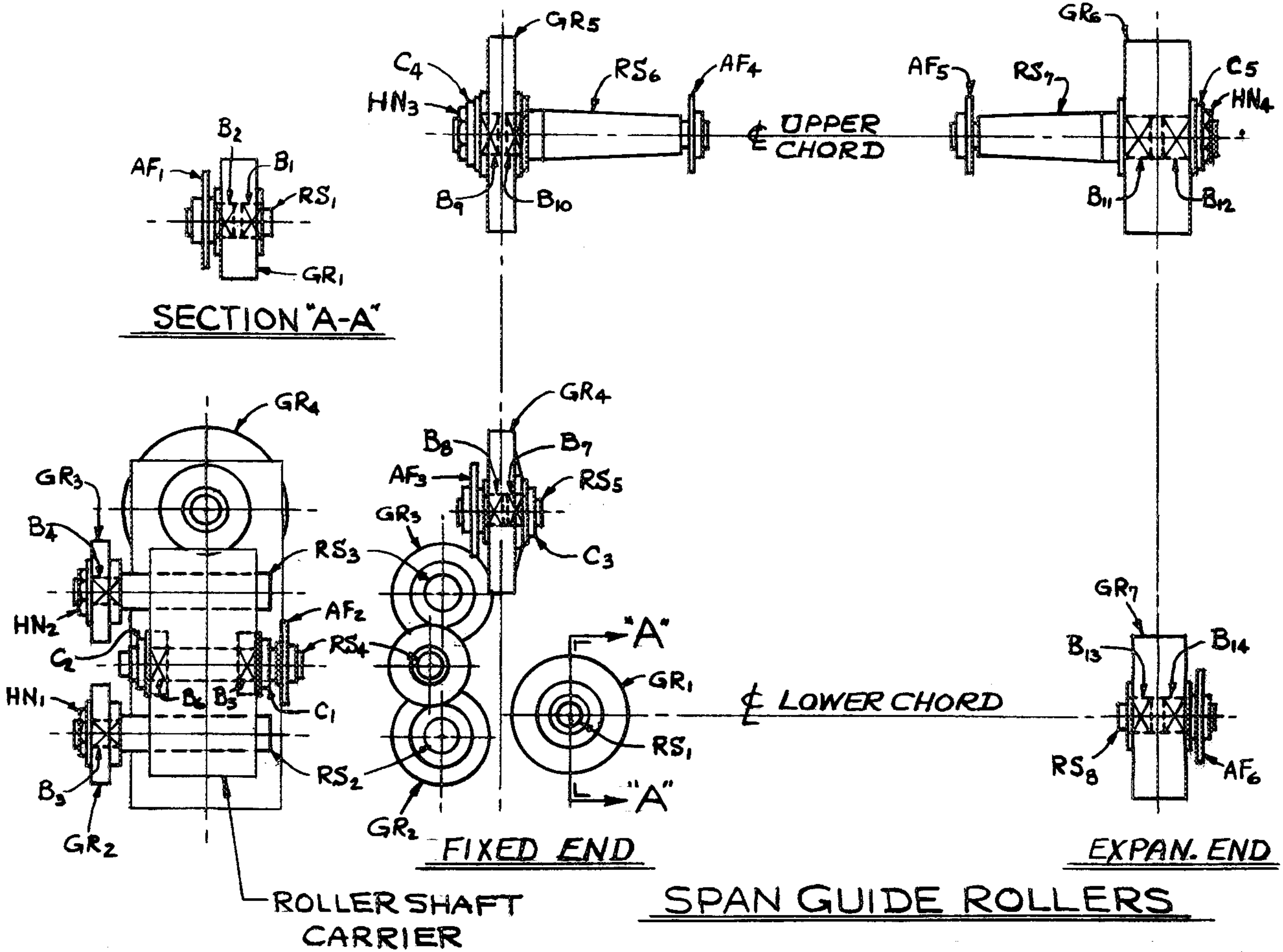
The time interval varies from 17 seconds to 22 seconds at the South Counterweight or 29.4%. The tension then varies 67.4%.

There was only one rope at each end of the span that vibrated through 30 cycles in 17 seconds. Only one rope at the south end took 22 seconds. If the 17 second and 22 second time intervals are eliminated, the time intervals at each end would be 3 seconds or 17.7%, and the maximum difference in tension would be 36%.

The average time interval for 30 vibrations is 19.5 seconds at each end of the span or 92.3 vibrations per minute. If the tension in the ropes were to be readjusted so that the time intervals were 19 or 20 seconds for 30 vibrations, the maximum tension difference would be 10%. This would require readjusting the tension in nine ropes at the north end and eleven ropes at the south end.

There are two auxiliary counterweight ropes at each corner of the lift span. The ropes are attached to the span near the top chord approximately 100 feet from the end. The ropes pass over the auxiliary counterweight sheaves in the tower then down to the auxiliary counterweight.

The auxiliary counterweight ropes are seriously corroded. They have not been lubricated for many years. The length of ropes from the top chord of the lift span to the sheave is difficult to reach and apparently has never been lubricated. The ropes are heavily pitted in this area, as seen in Photograph 78. At some time in the distant past, the part of the ropes that extend down from the sheaves to the counterweight were lubricated, as



SECTION "A-A"
AF_1
B_2
B_1
RS_1
GR_1
GR_5
C_4
HN_3
RS_6
AF_4
B_9
B_{10}
℄ UPPER CHORD
GR_6
AF_5
RS_7
C_5
HN_4
B_{11}
B_{12}
GR_4
GR_3
B_4
HN_2
C_2
HN_1
B_3
GR_2
RS_3
AF_2
RS_4
B_6
B_5
C_1
RS_2
ROLLER SHAFT CARRIER
B_8
B_7
AF_3
RS_5
C_3
"A"
GR_1
RS_1
"A"
FIXED END
℄ LOWER CHORD
GR_7
B_{13}
B_{14}
RS_8
AF_6
EXPAN. END
SPAN GUIDE ROLLERS

FIGURE 4

seen in Photographs 79 and 80. The lubricant that remains on the ropes is hard and cracked, as seen in the photographs. Water enters the rope through the cracks in the lubricant and through the spaces between bare wires. The outside surfaces of the ropes are corroded and internal corrosion has surely occurred.

The rope grooves in the northwest auxiliary counterweight sheave can be seen in Photograph 81. The grooves are coated with rust.

Guides

Span Guides

The span guides include single guide wheels at the four corners of the upper chord and at the two lower chords at the north end of the lift span. The span guides at the south end consist of three longitudinal rollers and one transverse roller at each corner, as seen in Figure 4.

All of the guide rollers were checked to see if they rotate freely, and also for general condition. All rollers rotate freely and appear to be receiving adequate lubrication.

The guide rollers on each side of the span were observed while the lift span was raised and lowered. The total clearance on the longitudinal guide rollers at the south end was approximately one inch at each corner. Total clearance for the transverse rollers was approximately 1-1/4 inch at each end.

Main Counterweight Guides

The guides for the main counterweights are slippers with slots that engage T-bar type guides riveted to the structural steel on each side of the tower. There are two guide shoes attached to the top of the counterweight and two at the bottom, all four are on the navigation channel side of the counterweight.

The T-bars were checked at 25 foot intervals for the entire height of travel. The T-bars were found to be well lubricated during the inspection. However, there is much etching of the sliding surfaces of the bars, as seen in Photograph 82. It would appear that they were neglected at some time in the past and suffered from substantial corrosion. There was water found trapped behind loose paint applied over the lubricant on the guides in several locations. The trapped water could also promote corrosion.

The thickness of the guides were measured at 25 foot intervals with a vernier caliper. The maximum thickness found was 1.610 inches and the minimum was 1.425 inches on the north tower. The thickness varies from 1.455 inches to 1.575 inches on the south tower. The guide extension on the T-bar is tapered. The measurements taken were at a depth approximated as 1-1/2 inches. A small part of the variation in thickness could be from variations in depth the measurement was taken at.

The full depth of the guides on the T-bar was measured with a scale. The depth varied from 3 inches to 3-3/8 inches.

The slots in the replaceable slippers were measured on each counterweight. The depth of the slots varied from 2-1/4 inches to 2-1/2 inches on the north counterweight. The width was 2-1/2 inches on each. On the south counterweight, the depth of the groove in the slippers varies from 2 inches to 2-1/2 inches and the width from 2-1/4 inches to 2-5/8 inches.

When the counterweight raises and lowers in a strong wind, there can be a substantial pressure between the surfaces of the guides and the surfaces of the slots in the slippers. The slippers wear and the guides wear. When the depth of the slots becomes too great, the slippers begin to rub the rivets that attach the guides to the structural steel. When this occurs, the slippers must be replaced.

When the guides wear, the depth of the guide is reduced by wear, as well as the width. As the depth is reduced, the slippers hit the rivets after less wear in the grooves of the slippers.

The guides and slippers are both made of steel. The type of steel the slippers have been made from in the past could not be determined. Two worn slippers were located in the U. S. Army Corps of Engineers' shop. Photographs 83 and 84 show the worn grooves and the area on each side of the grooves (on top) that have been contacting the rivets.

The slippers are relatively easy to replace and their cost is minimal. The cost to replace the guides would be much greater. Consideration should be given to changing the wearing surfaces of the slippers to a softer material, such as bronze. The rate of wear on the guides would then be reduced, extending their life.

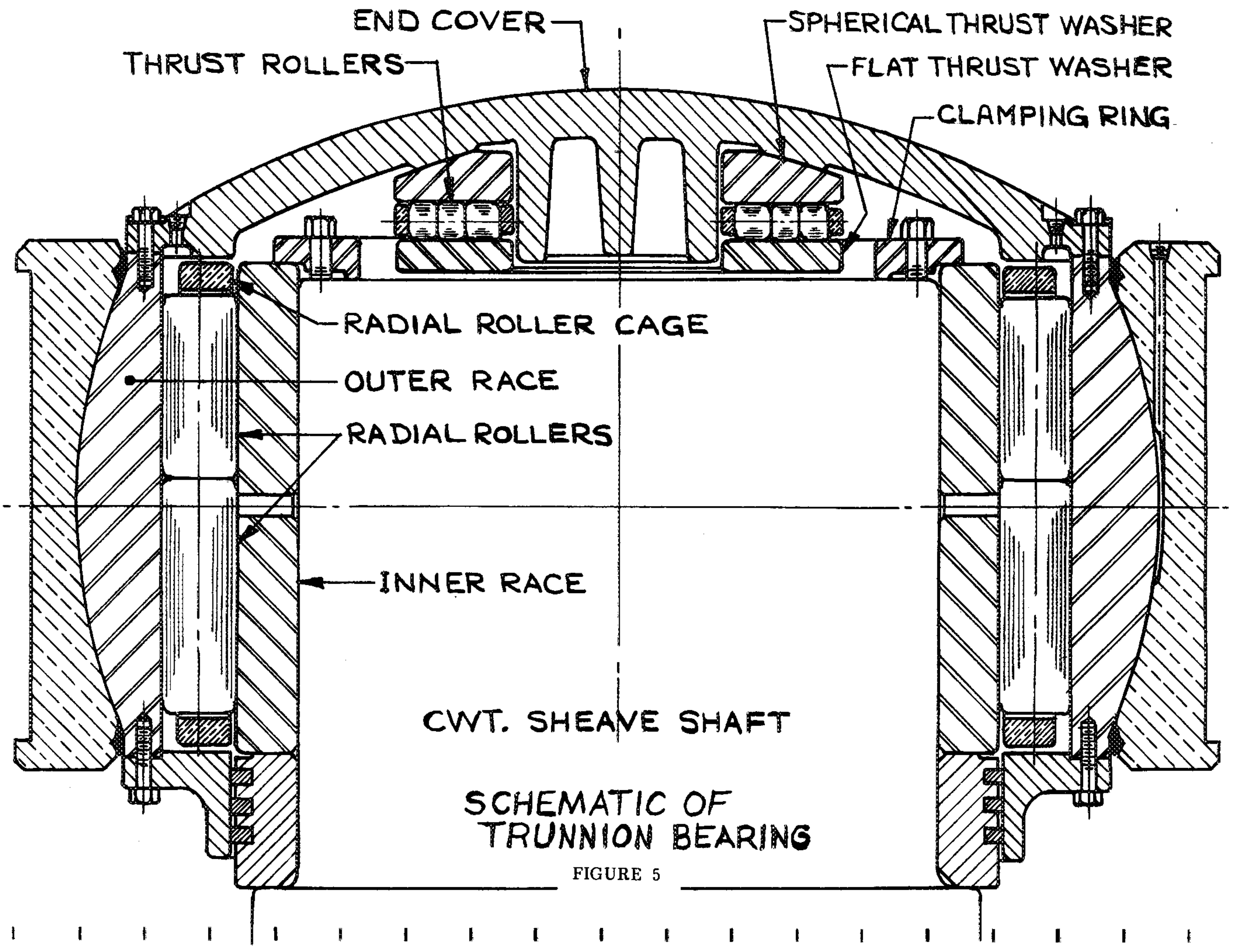
The auxiliary counterweights are guided by the same guide rails used for the Main Counterweights. There are four guides located on each auxiliary counterweight. They do not have replaceable slippers. The grooves in the auxiliary counterweight guides are worn, as seen in Photograph 85. The widths vary from 2-1/4 inches to 2-1/2 inches on the north auxiliary counterweight and the depth from 2 inches to 2-1/2 inches. On the south auxiliary counterweight, the grooves vary from 2-1/2 inches to 2-9/16 inches wide and 2-1/8 inches to 2-1/2 inches deep.

The mounting bolt nuts that hold the guide frames to the Main Counterweights are heavily corroded in many locations. The nuts should be replaced promptly and the nuts and bolts protected from corrosion.

Counterweight Trunnion Bearings

The sixteen roller bearings supporting the counterweight sheave shafts all have serious defects. The original intent was to open two bearings for internal inspection. William Slusarcyk, a field service representative from the bearing manufacturer was brought in to do the internal inspection.

Bearing TB_1 in the south tower was opened first, as seen in Photograph 86. While inspecting the bearing, steel shreds were found in the grease. Bronze flecks were also found. The source of the steel was found to be the boss on the inside of the end cover, as seen in Photograph 87.


END COVER
THRUST ROLLERS
SPHERICAL THRUST WASHER
FLAT THRUST WASHER
CLAMPING RING
RADIAL ROLLER CAGE
OUTER RACE
RADIAL ROLLERS
INNER RACE
CWT. SHEAVE SHAFT
SCHEMATIC OF
TRUNNION BEARING
FIGURE 5

Three elements of the thrust washer are supported by the boss, as seen in the schematic in Figure 5. The flat thrust washer rides on the end of the boss. The flat washer had worn a sizeable groove in the top of the boss, as seen in the photograph.

The thrust rollers were found to have substantial heat discoloration, as seen in Photograph 88. The spherical washer and the flat washer were also found to have heat discoloration. The side of the flat washer that the rollers contact can be seen in Photograph 89.

The grease was cleaned out of this bearing and it was flushed out with kerosene. The end cover was rotated 180 degrees to move the undamaged area of the boss to the top. The bearing was then reassembled and filled with new grease.

Trunnion Bearing TB_1 in the North Tower was then opened. The thrust rollers and both thrust washers were found to have heat discoloration in this bearing also. The roller side of the flat washer can be seen in Photograph 90 and the rollers in Photograph 91.

Two additional sources of steel contamination were found. The end of the counterweight sheave shaft presses against the flat washer at times. During rotation of the shaft, some slippage occurs causing some wear on the shaft. Also, the clamping ring holding the inner race of the bearing on the shaft is held in place by 20 hex head capscrews without washers. The capscrews were tightened with sufficient torque to cause the corners of the heads to dig into the clamping rings. Steel slivers were found around many of the capscrews.

Mr. Slusarcyk completed his inspection of the two bearings opened during his visit to the bridge. A copy of his report can be found in Appendix B.

A quick study was made to try to determine the cause for the intense heat generated in the thrust bearing and the cause for the rapid wear on the boss supporting the thrust bearing.

Several serious flaws in design of the trunnion bearing were found. First of all, the radial roller assembly is a group of cylindrical rollers mounted in a bronze cage that is free to float axially. The rotating assembly can float until the bronze cage comes into contact with the stationary end cover on either end of the bearing housing. The end covers are made of soft steel, ASTM A27-24. The machined surfaces that the bronze comes into contact with have a very rough finish, approximately 250 microinches. When the rotating soft bronze comes into contact with the stationary rough steel surfaces, the bronze abrades very quickly.

The usual procedure to restrict end float of cylindrical roller bearing assemblies is to provide shoulders on the inner and/or outer races. The ends of the hard polished rollers contacting hard polished shoulders does not create a problem. The bearings on the Buzzards Bay Bridge do not have shoulders on either the inner or outer race. The outside diameter of the inner race and the inside diameter of the outer race are both pure cylinders, as shown in Figure 5.

The thrust bearing has several serious design deficiencies. The outside diameter of the boss supporting the three thrust bearing components is the same soft steel with the same rough surfaces mentioned above. The flat thrust washer theoretically rotates at the speed of the counterweight sheave shaft. The thrust roller assembly in its bronze cage rotates at half the speed of the same shaft. The flat washer and bronze cage both rotate on the soft steel boss with a poor surface finish. Again, the bronze and the steel boss will both wear.

The space between the end of the counterweight sheave shaft and the flat washer is designed to be 1/4 inch. The bearing at the other end of the shaft also has 1/4 inch space available. When the sheave assembly moves in one direction until the 1/4 inch gap is taken up, the bearing at the other end of the shaft will have 1/2 inch gap. The chamfer at each end of the inside diameter of the flat washer is 1/8 inch on the drawings. The cylindrical part of the inside diameter is 7/8 inch long. Therefore, with the 1/2 inch gap and the flat washer moved up against the shaft, there would only be 1/4 inch of the bore of the washer in contact with the boss <u>if</u> everything were made exactly to print and the two bearing housings were mounted <u>exactly</u> at the proper distance apart. If a combination of machinery errors on <u>any</u> of the parts in the bearing assembly or the sheave assembly or an error in spacing between the two bearing housings were to add up to 1/4 inch or more, the flat washer would fall off from the end of the boss. If the combination of errors were to be more than 1/4 inch, but less than 3/8 inch, the flat thrust washer would ride with the chamfer riding on the edge of the boss. The line contact between the end of the boss (soft steel) and the rough surface of the chamfer on the hard thrust washer would cause rapid wear of the boss.

An attempt was made to determine the relative spacing between pairs of bearings supporting each counterweight sheave shaft. The space between the seal ring of each bearing and the hub of the heave was measured on both sides of each sheave. The total space for the sheaves varies from 1-13/16 inches to 2-1/8 inches or a maximum difference of 5/16 inch. This would indicate that the spacing between pairs of bearings varies 5/16 inch. The difference in spacing between trunnion bearings alone is sufficient to allow the flat thrust washer to slide off the boss and rest with the only contact between the washer and the boss in the chamfer.

The thrust rollers are cylindrical. The thrust roller assembly includes fifteen sets of three rollers held in radial pockets in the bronze cage, as seen in Figure 5 and Photograph 88.

Cylindrical rollers do not like to roll around in circles, as they must in this bearing. When forced to roll in circles, the rollers must slide on both of the thrust washers.

With three rollers of the same diameter in each radial pocket, the three rollers must rotate at different speeds. The flat ends of the abutting rollers must slide rotationally with respect to one another. No provision was made to lubricate the abutting ends of the rollers. The sliding of the rollers on the two thrust washers and the unlubricated abutting ends of the rollers rotating against one another all create heat quickly when operating under load. It is this heat that is generated that caused the heat discoloration of the thrust rollers and thrust washers.

Another questionable feature in the thrust bearing design is the mating surfaces between the spherical thrust washer and the end cover. The surface in the end cover is the frustrum of a cone. The mating surface on the washer is spherical. Therefore, only line contact can occur between the two pieces.

After defects were found in the first trunnion bearings opened, the decision was made to open the other fourteen trunnion bearings. This was done. Substantial amounts of bronze were found in all bearings. Steel flakes and slivers were found in eight bearings. All fourteen of the bearings were flushed out with kerosene and refilled with new grease. Several of the bearings were found with excessive wear on the boss in the end cover that supports the thrust bearing. In each case, the end cover was rotated 180 degrees to place the unworn area of the boss in the load zone.

The access to internal parts of the radial bearing is very poor, even with the end cover removed. Note in the schematic in Figure 5 that the space between the inner and outer races at the ends of the rollers is almost completely covered by the bronze roller cage. Visual access to areas beyond the ring of the bronze cage is virtually non-existent.

The bearing surface on the inner race is completely inaccessible. A small percentage of the bearing surface of the outer race and on the rollers can be checked "by feel" with a bent wire. This was done on each bearing. A straight stiff feeler wire was made with 1/2 inch of the end bent 90 degrees from the rest of the wire. The bent end of the wire had a sharp point. To check the bearing, the bent end was inserted between two rollers and first positioned so as to hold the sharp end of the wire against the bearing surface of the outer race. The wire was then pushed in and pulled out the full width of the bearing while holding the tip against the outer race.

The tip of the wire was then turned so that the tip could be held against the rollers on one side of the opening and the wire run in and out the full width of the bearing with the tip held against the roller. This was repeated for the second roller on the opposite side of the opening.

The above procedure was repeated for all of the openings in the lower half of the bearing. Since the top half of the outer race is never in the load zone, it was not checked. The rollers in the top half of the bearings were spot checked.

Using the above procedure, many rough spots were found in the outer races and in the rollers. In some cases, a rough spot was found, then lost. It could not be relocated.

The rough spots could be several things. Rolling element bearings that fail by fatigue frequently have flakes of metal dislodged from the bearing surfaces, leaving a pit with a rough surface. The primary purpose of the inspection was to see if any of this type of degradation was present. It may very well be.

The presence of steel slivers and bronze in the oil as explained earlier complicates the analysis of the rough spots. Large slivers of steel were found that had worn away from the bosses in the end covers. Much bronze was also found, but no large pieces.

The flakes of steel found in the grease could be from one of two sources. Undoubtedly, some of the slivers of steel from the worn boss found its way into the radial bearing. When the slivers were rolled over by the rollers in the load zone, they would have been flattened out into flakes. The second potential source for the flakes would be from degradation of the bearing components.

The rough spots found could have been caused by surface fatigue of the bearing elements. They also could have been steel slivers that had been rolled over that were still adhering to the bearing surface. The rough spots that were found then could not be relocated, could have been steel flakes that were dislodged by the sharp end of the wire. However, no flakes were ever drawn out by the wire when this occurred.

Another possibility for the rough spots would be depressions in the bearing elements caused by the steel slivers that were rolled over while in the radial bearings.

Steel slivers and flakes found in eight bearings were sent to Torrington for their analysis. They checked the flakes with an electron microscope and have concluded that all pieces sent in were from the bearing boss, not from the rollers or races. This information is included in their report in Appendix B.

Observations made in the fourteen additional trunnion bearings opened are as follows:

TB_2 South - The thrust rollers and both washers have heat discoloration. Slivers of steel and bronze were found in the grease. Rough spots were found in the outer race near the bottom.

TB_3 South - Steel slivers found around clamping ring bolts. Thrust rollers and washers discolored. Rough spots found in outer race.

TB_4 South - Bronze and steel were found in grease. The boss supporting thrust bearings has worn 1/32 inch. Thrust rollers and washers are discolored. Seven pieces of steel were found in grease.

Severe heat discoloration on the thrust rollers can be seen in Photographs 92 and 93. Severe heat discoloration on the flat side of the spherical washer is shown in Photograph 94. Line contact on the spherical side of the spherical washer is shown in Photograph 95. Substantial heat discoloration on the roller side of the flat washer is shown in Photograph 96.

TB_5 South - This bearing has not been in contact under load for a long time, if ever. The axial thrust has apparently been toward TB_6 supporting the opposite end of the shaft. However, steel and bronze were found in the grease. Photograph 97 shows the thrust roller assembly. Both sides of the assembly, including the rollers, were coated with old grease.

TB_6 South - Much bronze was found in the grease. The boss in the end cover is heavily scored, as seen in Photograph 98. Note also in the photograph that bronze has been pressed into the conical area of the end cover contacted by the spherical thrust washer. The inside diameter of the flat thrust washer was also scored, as seen in Photograph 99. Hard contact between the end of the shaft and the flat washer has scored both parts. The thrust rollers are badly discolored, as seen in Photograph 100. Both thrust washers also have heat discoloration, as seen in Photographs 101 and 102. Several rough spots were found in the outer race. The outside diameter of the clamping ring has been contacting the inside of the end cover in this bearing.

TB_7 South - The grease in this bearing was contaminated with bronze. Wear on the end of the bronze cage in the radial bearing was especially severe, as seen in Photograph 103. Bronze pickup on the end of the shaft can be seen in Photograph 104. The boss supporting the thrust bearing parts is worn. Both of the thrust washers had been rotating on the boss. Both thrust washers have heat discoloration, as seen in Photographs 105 and 106. The thrust rollers are severely discolored, as seen in Photograph 107. Several rough spots were found in the outer race.

TB_8 South - A piece of rag and bronze were found in the grease in this bearing. The boss supporting the thrust bearing has mild wear, as seen in Photograph 108. Bronze can also be seen pressed into conical surface of the end cover in the photograph. Heavy contact between the flat washer and the shaft has caused wear, heat discoloration and bronze pickup on the shaft, as seen in Photograph 109, and on the washer, as seen in Photograph 110. Bronze pickup and surface distress on the spherical side of the spherical washer can be seen in Photograph 111. A water level was used to check the level between several pairs of bearings, including TB_7 and TB_8 South. This is a crude method, but the only one available. Each pair of bearings checked were found to be level by this method.

TB_2 North - The boss supporting the thrust bearing is moderately worn. The roller side of the flat thrust washer has heat discoloration and is pitted, as seen in Photograph 112. The pits appear to be typical fatigue degradation. The shaft side of the flat washer also has discoloration and surface degradation, as seen in Photograph 113. One pit was found on a thrust roller. The rollers are severely discolored, as seen in Photograph 114. Bronze was found in the grease.

TB_3 North - The boss supporting the thrust bearing is moderately worn. The thrust rollers and washers all have heat discoloration. Photograph 115 shows the roller side of the flat washer. Nine radial rollers were found to have rough spots. Three rough spots were found on the bearing surface of the outer race. Bronze was found in the grease.

TB_4 North - The grease in this bearing was heavily contaminated with bronze. The end of the radial bearing cage is heavily abraded, as seen in Photograph 116. Several small casting defects were found in the bronze. One can be seen in the photograph. Heavy bronze pickup can be seen on the end of the shaft in Photograph 117. The thrust rollers are moderately discolored, as seen in Photograph 118. Pits were found on the roller side of the flat washer, as seen in Photograph 119. The spherical washer is heavily stained, as seen in Photograph 120. The stains do not appear to be heat discolored. They look like a corrosive liquid may have been splashed on the part at some some time. Rough spots were found on five radial rollers with the wire. Five rough spots were also found on the outer race.

TB_5 North - The grease was contaminated with steel and bronze in this bearing. All components in the thrust bearing have heavy heat discoloration. Photograph 121 is a closeup of thrust rollers. Photograph 122 shows the roller side of the flat washer. Photograph 123 shows the roller side of the spherical washer. The inside diameter of the flat washer is heavily scored, as seen in Photograph 124. The spherical side of the spherical washer has surface degradation, as seen in Photograph 125. The spherical washer has considerable amount of rust and light bronze pickup, also, as seen in Photograph 126. The boss supporting the thrust bearing is moderately worn. When checked with a wire, rough spots were detected on the outer race and eight on the rollers.

TB_6 North - The grease in this bearing was contaminated with bronze. The end of the radial bearing bronze cage is moderately worn. The thrust washers have bronze pickup, numerous rust spots and moderate heat discoloration. The roller side of the flat washer can be seen in Photograph 127. The thrust rollers are moderately discolored, as seen in Photograph 128. The flat washer has been sliding on the end of the trunnion shaft. Much bronze has been picked up on the end of the shaft. It has light wear. Three rough spots were detected on the outer race and four on the rollers when checked with a wire. Bearings TB_5 and TB_6 on the North Tower were checked with a water level. They are as level as can be ascertained by this method.

TB_7 North - Bronze and steel contamination was found in this bearing. There is no evidence that this bearing has carried a thrust load through the rollers. The flat washer slipped off from the end of the boss and wore a deep groove 1/4 inch wide into the end of the boss. Any thrust loads the bearing was subjected to have been transmitted from the trunnion shaft, through the slot washer, to the boss in the end cover. This is the counterweight sheave shaft that has the trunnion bearings farthest apart. It would appear that the first time the thrust was toward TB_8, the space between the end of the trunnion shaft and the boss supporting the thrust bearing in TB_7 was great enough to allow the flat washer to drop off from the end of the boss. The chamfer on the inside diameter of the flat washer rode on the end edge of the boss and wore the groove in the boss. With the flat washer wedged between the shaft and boss, the sheave assembly supported by TB_7 and TB_8 had no end float available for thermal expansion. The rollers and thrust washers have much rust. The cover was rotated 180 degrees when reassembled, but the excess space will permit the flat washer in either TB_7 or TB_8 to fall off from the end of the boss again and start the wear process over again. Ten rough spots were detected on the outer race with a wire and seven spots on the rollers.

TB_8 North - The grease in this bearing was contaminated with bronze and steel. The thrust rollers and both washers are discolored. The roller side of the flat washer can be seen in Photograph 129 and the rollers in Photograph 130. This thrust bearing has been subjected to heavy thrust loads, due to a lack of clearance available for thermal expansion, as explained under TB_7 observations. As a result, the flat washer has been in hard sliding contact with the end of the trunnion shaft. The degradation on the shaft side of the washer can be seen in Photograph 131.

Grease samples were taken from each of the sixteen trunnion bearings and sent to Ana Laboratories for analysis. A copy of each report is included in Appendix B. Their analysis was that TB_2 North had iron and copper "mildly above normal, but acceptable"; TB_5 and TB_6 North, plus TB_1, TB_4, TB_5, and TB_6 South with iron and copper "moderately high (abnormal)"; TB_7 and TB_8 North and TB_8 South with copper "moderately high (abnormal)"; TB_1 North, iron and copper "high (abnormal)"; and TB_3 and TB_4 North iron, copper and aluminum "high (abnormal)". The source of the aluminum is unknown, unless some of the bronze cages contained aluminum.

Plumbing

The plumbing in the control house was inspected by George Jackson of Jackson Plumbing and Heating, Inc., Bourne, Massachusetts. A copy of his report is contained in Appendix B.

Basically, the plumbing is in poor condition. There is no working toilet available to the bridge operators. The lavatory in the control house is cracked. A four inch sewer drain empties into the canal and the drain line is cracked. The water heater "appears to be leaking".

The lack of toilet facilities and the drain that empties into the canal are illegal under Massachusetts State plumbing laws.

Conclusions

The maintenance of machinery on this bridge is good in most areas at the present time. It would appear that, at times in the past, it was neglected. The most serious maintenance problem at the present time appears to be inadequate lubrication of the main counterweight ropes and the auxiliary counterweight ropes. The machinery driving the span locks and rail locks have all been neglected until recently, but the parts that had been neglected are now being cared for.

The most frequently neglected items on movable bridge drives are the fasteners. The first items that must be replaced, due to corrosion are always the fasteners. This bridge is no exception. Many of the bolts and nuts in all systems require replacement.

One problem with fasteners is that when a wrench is applied to the bolt heads and/or nuts, the paint is chipped off. No one ever repaints them. It would be wise to have a hard and fast rule that anyone that carries a wrench also must carry a kit to clean and repaint the bolts and nuts. If not paint, then some other rust preventative coating. Also, during lubrication, it would be well to look at bolts and nuts on each piece of machinery. If the person doing the lubricating has a kit available to him when he notices a fastener that is beginning to corrode, he can touch it up to stop the corrosion from progressing.

The operation of the span drive machinery has been altered by holding the cone clutch in the differential in the disengaged position. The reason for this change should be determined. The span drives do not operate as they were originally designed to do because of the change. The machinery operates satisfactorily as now altered, but the original design is superior, unless some unknown flaw or circumstance made the change advisable.

The 50 HP emergency motor drives for the operation of the span may never be used. The emergency generator has sufficient capacity to operate the span drives at full capacity. However, all of the machinery is available to operate the bridge at reduced speed with the 50 HP motor if ever required. The parts should be maintained to keep the drive useable.

The bearing journals on the emergency drive idler gear shafts should be polished and then protected from corrosion in the event they are needed. The bearings, motor coupling and motor brake should all be included in the maintenance procedure to prevent them from deteriorating.

The machinery brakes should not be required to retard the span while seating. If the buffer cylinders were all functioning properly, it would not be necessary to apply the machinery brakes to control closing speed. Some operators prefer to have one shoe on each machinery brake in contact with the brake wheel when the brakes are released to help retard the span. But if the controls are set up properly, the span is properly balanced, and the buffers are operating properly, no drag brake should be required.

The buffers on this bridge are not building up adequate pressure. They are also not piped to obtain a balanced resistance in the two corners of each end of the bridge. After the buffers have been rehabilitated, the operation of the span can be improved.

The maintenance of the drive machinery for the span locks and rail locks has now been improved. The maintenance problem remaining is the protection of the fasteners.

The counterweight guide T-bars have worn considerably and they need to be protected to retard further deterioration. The design of the slippers used to guide the main counterweights should be altered to provide a replaceable bronze insert. Guide wear should be taken into consideration in the design of the bronze inserts. The bronze will reduce friction between the guides and the inserts and reduce wear on the guides.

The upper span locks have not been used for many years. If the locks on the expansion end of the tower were to be in hard engagement while the lift span went through a substantial temperature change, it is quite likely that they would be damaged. The upper locks could be positioned so as to prevent the lift span from descending with no power applied in the event of failure in the system. The bridge must be out of balance and/or have several brakes in the span drives fail to permit the span to descend with no power applied. The bridge has operated successfully for many years without the locks in operation. The cost to reactivate the system may not be justifiable.

The most serious problems that exist on the Buzzards Bay Bridge are the deficiencies in the counterweight ropes (main and auxiliary) and in the counterweight trunnion bearings. These problems must be addressed promptly.

The degradation of the auxiliary counterweight ropes is such that they should be replaced as soon as possible. The deterioration of the main counterweight ropes is not as clear cut. They may very well be in serious condition also. The corrosion that is apparent in the valleys of the ropes appears to be two kinds, oxidation corrosion due to water in contact with the wires instead of oil, and fretting corrosion due to wires in adjacent strands rubbing together.

The damage to the ropes at the rope guides at the counterweight connection also is serious. The ropes have been weakened due to damage.

The only positive way to determine the loss of strength in the main counterweight ropes is to take at least one out and test it to destruction. The rope can then be opened up to see how serious the corrosion damage is also. However, there is no assurance that the rope selected for test purposes has corrosion damage that is average, one of the best, or one of the worst.

Measures can be taken and should be taken to reduce the rate of deterioration of the ropes until they are replaced. Restraints can be designed to substantially reduce the pounding of the ropes against the upper guides, due to wind induced rope vibration. The ropes need to be cleaned thoroughly and properly lubricated promptly.

One of two approaches can be followed for the final fix on the main counterweight ropes. The safest path to follow would be to replace them as soon as practical. The second approach would be to select the rope with the most visible damage, (Rope #6 at the South counterweight seems to be the likely candidate) replace it with a new rope, then make a decision as to whether the ropes need to be replaced based on the tests.

The trunnion bearings need to be repaired or replaced promptly. Torrington's recommendation is to replace all parts with heat discoloration. The heat necessary to produce the discoloration observed would also soften the steel substantially. Virtually all parts of thrust bearings should be replaced.

It would be foolhardy to replace the damaged bearings in kind. The replacements should be bearings that will not necessitate sliding between parts that will generate heat and create wear.

The radial bearings are not as clear cut a case, since the apparent damage detected was not visible and not as severe. However, there is no way that the end float of the radial roller assemblies can be eliminated without disassembly of the bearings. To disassemble the bearings, the counterweights must be separately supported, the counterweight ropes disconnected, and each sheave assembly raised out of the bearings supporting it. If this is done, new bearings should be available when the bearings are disassembled and the new bearings installed, rather than try to salvage the existing bearings.

Hopefully new bearings can be provided that will fit into the existing bearing housings. If tapered roller bearings are used, (such as shown on the original design drawings) the separate thrust bearings would be eliminated. Spherical roller bearings could also be used to provide both the radial and thrust capacity required.

Both the counterweight rope replacement and bearing replacement can best be done by separately supporting the counterweights. A substantial amount of money could be saved by doing both jobs at the same time.

Recommendations

1. Institute a program to replace all corroded bolts and/or nuts. This includes:

    a. Assembly bolts on machinery such as:

        1. Connecting rods on lock bars

        2. Speed reducers

        3. Buffer cylinders

4. Bearing caps

5. Span guides.

b. Mounting bolts for all machinery components.

c. Foundation bolts for the lower span machinery.

2. Clean, polish and protect the bearing journals on the idler gear shafts for the 50 HP emergency span drives. Include all components of the emergency drive in preventive maintenance program.

3. Reactivate limit switches on all span drive brakes, making sure that they are properly interlocked in the control circuit.

4. Replace check valves and pressure regulating valves on all buffers. Connect pairs of buffers at each end of span and in each tower with piping and one pressure regulating valve to equalize pressure in each pair of buffers. Adjust pressure regulating valve to build up sufficient pressure during seating of the span to eliminate the necessity of setting the machinery brakes during seating.

   After replacing valves and repiping the buffers, if the proper pressure cannot be obtained in any cylinder, that cylinder should be disassembled and rehabilitated as necessary.

5. Replace Gearset PG_1-SG_1 in both lower span lock drives.

6. Determine why the clutches in the span drive differential have been deactivated. Unless some compelling reason is found why they must be deactivated, they should be reactivated.

7. Interim procedure:

   a. Clean and relubricate all existing main and auxiliary counterweight ropes. Use a lubricant that will penetrate the core of each rope and displace water.

   b. Provide vibration limiting devices on counterweight ends of all counterweight ropes.

   c. Remove all debris from area of counterweight rope socket at attachments to the counterweights.

8. Replace guides at rope attachments at counterweights.

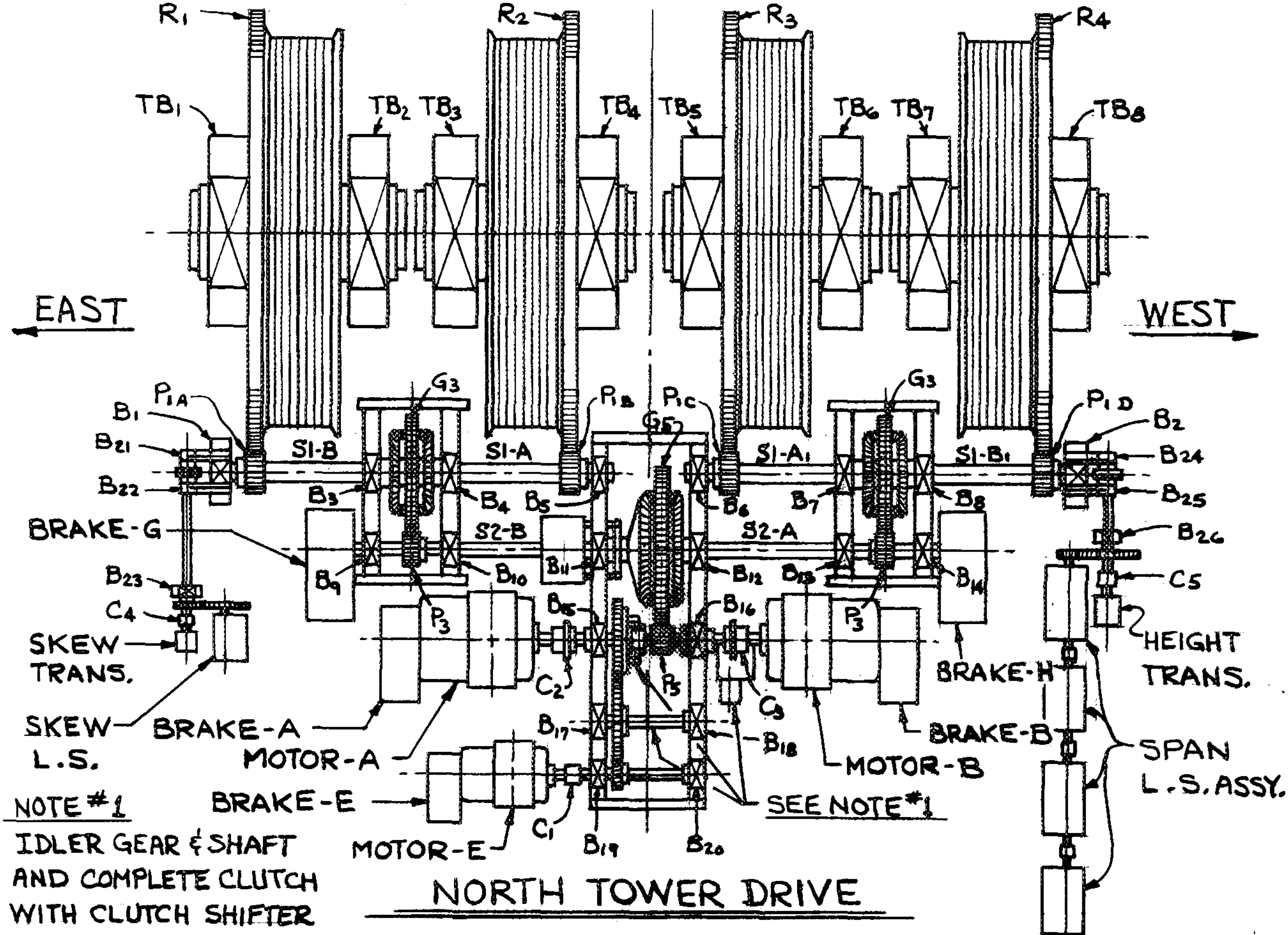
9. Provide permanent vibration limiting devices at counterweight ends of ropes to reduce abrasion between ropes and grooves in guides.

10. Replace all main and auxiliary counterweight ropes as soon as practical.

11. Replace counterweight trunnion bearings assemblies. Use bearings that are dimensionally interchangeable with existing bearings so that existing bearing housings can be reused. Replacement bearings should be spherical roller or tapered roller types that provide both radial and thrust capacity. One bearing on each trunnion shaft should be fixed and the second bearing should float to allow for differential thermal expansion.

12. Replace the entire plumbing system in the control house, per the recommendations included in George Jackson's report in Appendix B.

13. Redesign counterweight guide slippers to provide bronze slipper inserts in each slipper.



NOTE #1

IDLER GEAR & SHAFT AND COMPLETE CLUTCH WITH CLUTCH SHIFTER MECH. HAVE BEEN REMOVED.

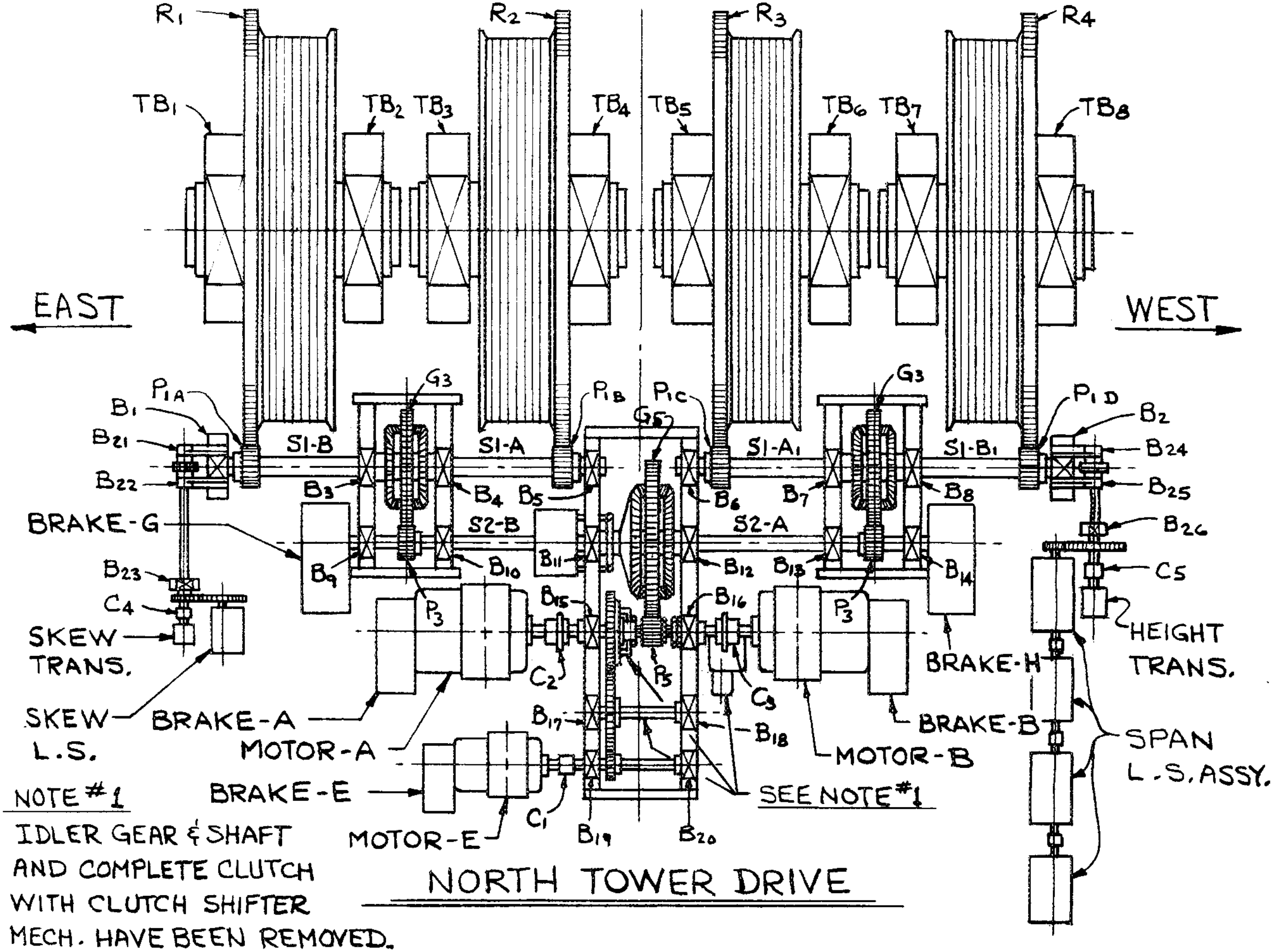
NORTH TOWER DRIVE

NORTH TOWER

BEARINGS

TABLE 1

BEARING	CLEARANCE ORIGINAL	CLEARANCE CURRENT	WEAR	REMARKS
B_9	.005"	.012"	.007"	Opened - Good condition.
B_{10}	.005	.001	NIL	
B_{11}	.005	.011	.006	
B_{12}	.005	.018	.013	
B_{13}	.005	.002	NIL	Opened - Light scratching on journal, not well polished, deep scoring in cap, old dry grease
B_{14}	.005	.011	.006	
B_{15}	.005	.019	.014	Opened - Good condition.
B_{16}	.005	.007	.002	Opened - Good condition.



NOTE #1

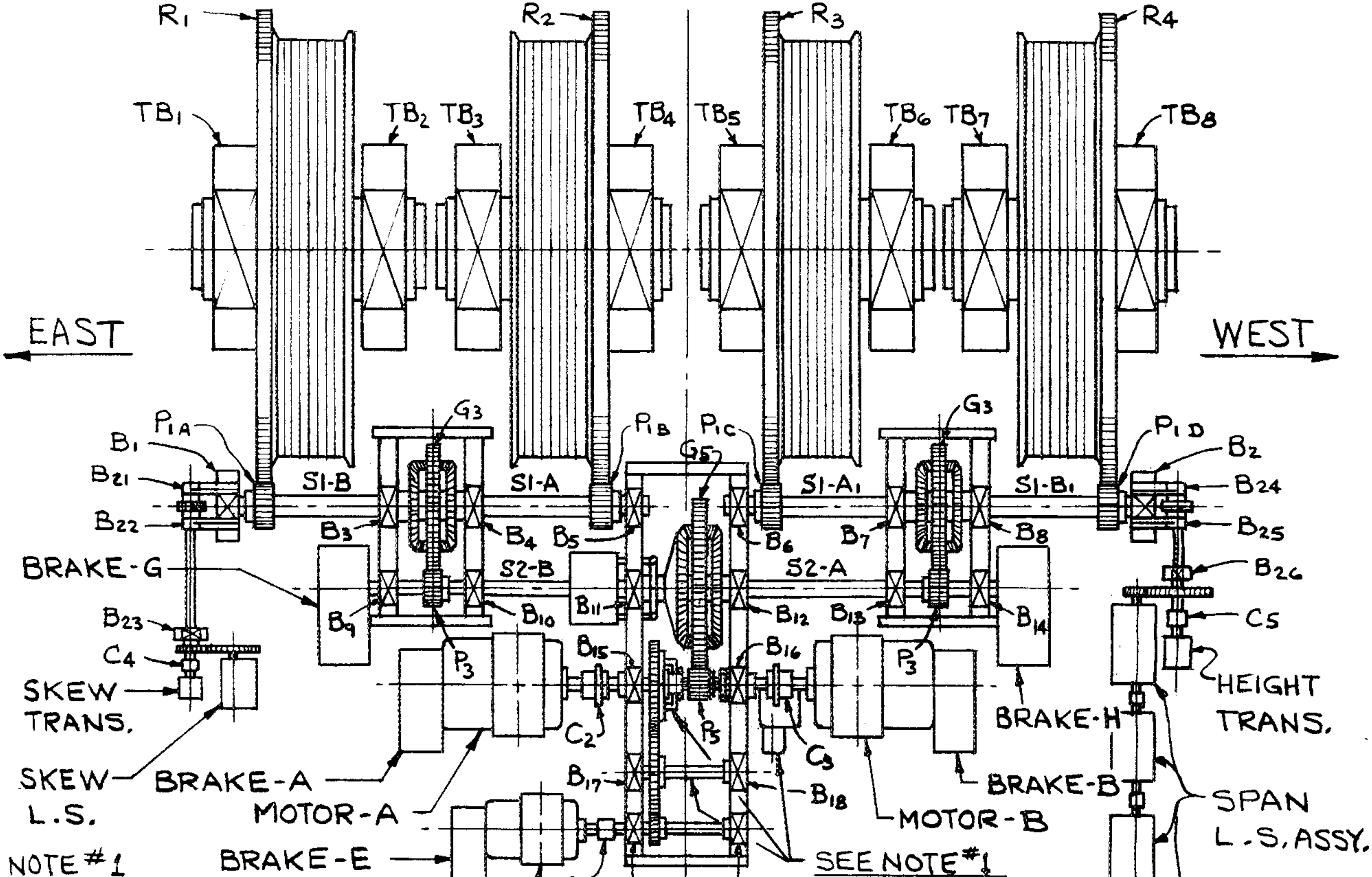
IDLER GEAR & SHAFT AND COMPLETE CLUTCH WITH CLUTCH SHIFTER MECH. HAVE BEEN REMOVED.

NORTH TOWER DRIVE

TABLE 2

NORTH TOWER

GEAR IN QUESTION				GEAR TOOTH MEASUREMENTS						WEAR		BACKLASH	
Gear	Circular Pitch (CP) ~~or Diametral Pitch (DP)~~	Number of Teeth in Gear	Pressure Angle in Degrees	Type of Measurement Span or Chordal Tooth Thickness	For Span - Number of Teeth Span Taken Over	"As Built" Measurement	Present Measurements — Position on Tooth Measurement Taken: EAST	MIDDLE	WEST	Inches	Percent of Original Tooth Thickness	Original	Present
G_5	1.50	120	20	Span	17	24.073	-	24.014	-	.059	7.9	- NOT SHOWN ON SHOP DRAWINGS -	
P_5	1.50	19		Span	3	3.653	3.639	41	41	.014	1.9		
G_3-West	1.75	80		Span	11	17.891	17.837	17.838	17.839	.054	6.2		
P_3-West	1.75	21		Span	3	4.275	4.252	56	49	.026	3.0		
G_3-East	1.75	80		Span	11	17.891	17.838	37	37	.053	6.1		
P_3-East	1.75	21		Span	3	4.275	4.251	54	51	.024	2.7		
R_4	2.25	280		Chordal		1.125	1.109	12	15	.016	1.4		
P_1D	2.25	19		Span	3	5.476	20	25	30	.056	5.0		
R_3	2.25	280		Chordal		1.125	1.113	16	24	.012	1.1		
P_1C	2.25	19		Span	3	5.476	24	26	25	.052	4.6		
R_2	2.25	280		Chordal		1.125	1.108	15	11	.017	1.5		
P_1B	2.25	19		Span	3	5.476	29	31	28	.048	4.3		
R_1	2.25	280		Chordal		1.125	1.114	24	24	.011	1.0		
P_1A	2.25	19		Span	3	5.476	5.425	26	23	.053	4.7		



NORTH TOWER DRIVE

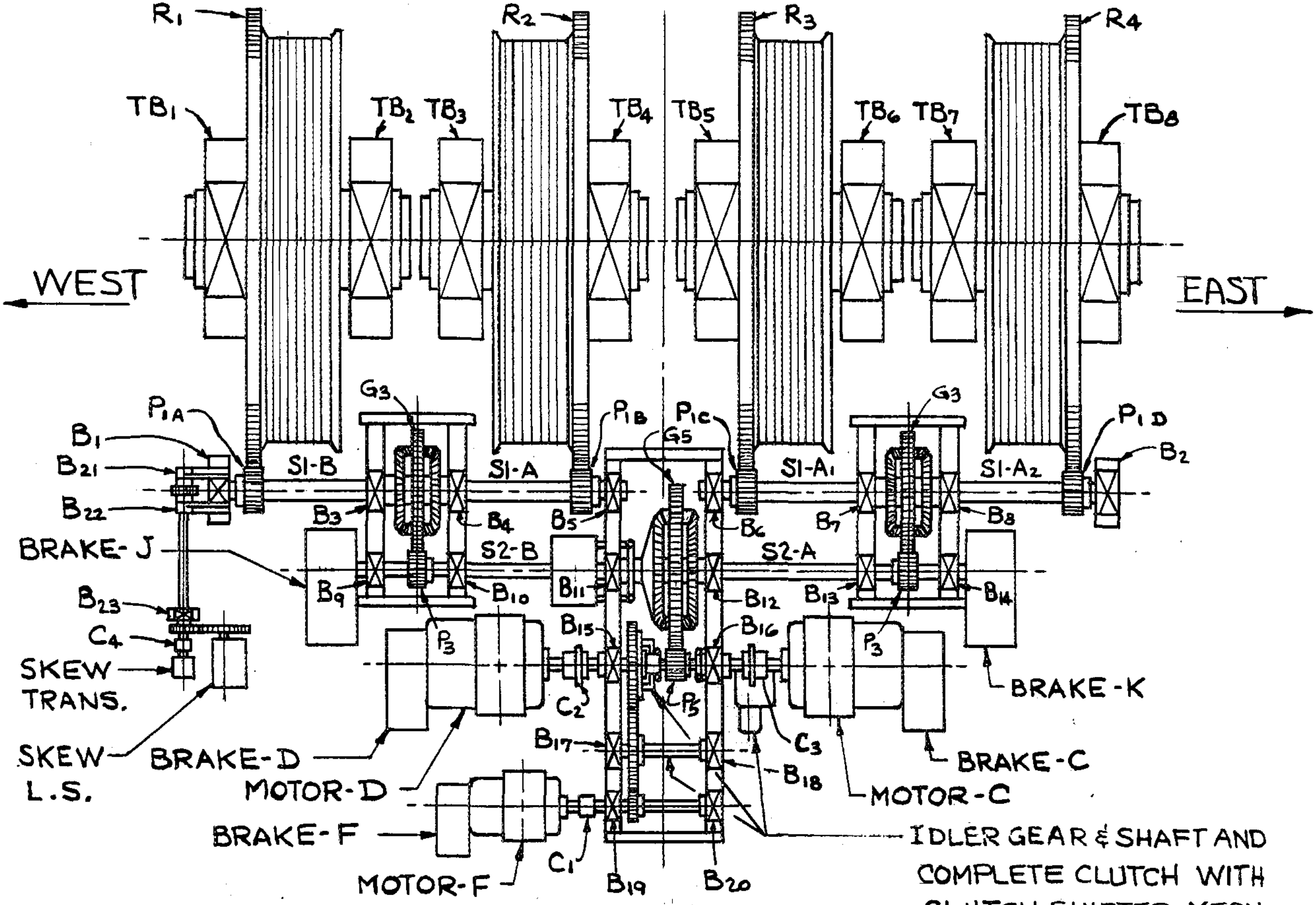
NOTE #1

IDLER GEAR & SHAFT AND COMPLETE CLUTCH WITH CLUTCH SHIFTER MECH. HAVE BEEN REMOVED.

TABLE 3

SPAN DRIVE COMPONENTS
NORTH TOWER

PART NAME	#	REMARKS
BRAKE	A	Limit switch doesn't actuate. Lining 3/8". OD of brake wheel not polished. Gap = 1 3/16".
BRAKE	B	Lining 3/8". Brake wheel nicely polished. Limit switch sluggish. Gap = 7/8".
BRAKE	E	Lining 3/8". OD of brake wheel rusty. Big spaces, shoes to drum when released. Gap = 3/4".
BRAKE	G	Lock nut on brake shoe adjustment backed off. Lining 1/2". Old moderate scoring on brake wheel. Gap=2 1/4"
BRAKE	H	OD brake wheel - one old groove. Limit switch doesn't actuate. Lining 1/2" & 7/16". Gap = 2 5/16".
COUPLING	C_1	Opened - Inadequate lubrication. No other deficiencies found.
COUPLING	C_2	Opened - Lubricant OK. No other deficiencies found.
COUPLING	C_3	Opened - Lubricant OK. No other deficiencies found.



SOUTH TOWER DRIVE

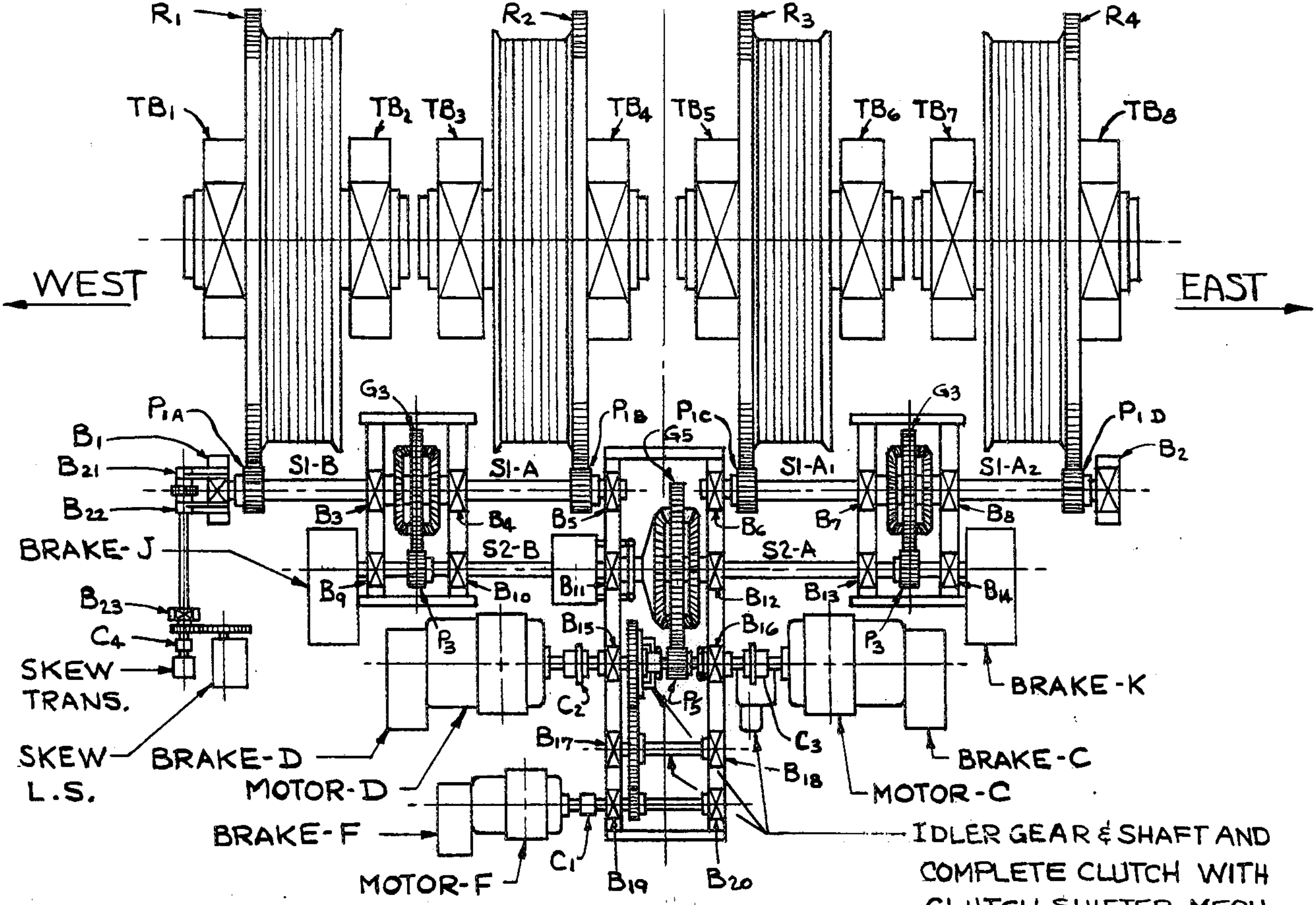
SOUTH TOWER

BEARINGS

TABLE 4

BEARING	CLEARANCE ORIGINAL	CLEARANCE CURRENT	WEAR	REMARKS
B_2	.006	.016	.010	Clearance is in bottom. Gear tooth load may be holding shaft up.
B_9	.005	.012	.007	Opened - Only 35% contact.
B_{10}	.005	NIL *	NIL	Opened - Journal has minor scoring. 60% contact.
B_{11}	.005	.014	.009	
B_{12}	.005	.011	.006	
B_{13}	.005	.005 *	NIL	Opened - Good condition. Good alignment. 100% contact.
B_{14}	.005	.010	.005	Opened - Shaft poorly aligned with bearing. Minor scoring on journal. Only 10% contact
B_{15}	.005	.012 *	.007	Opened - Minor scratching on journal. Poor alignment. 10% contact.
B_{16}	.005	.015 *	.010	Opened - Minor scratching on journal and in cap. Poor alignment. 25% contact.
B_{23}	.004	NIL *	NIL	No significant wear.

* CLEARANCES TAKEN WITH A DIAL INDICATOR.

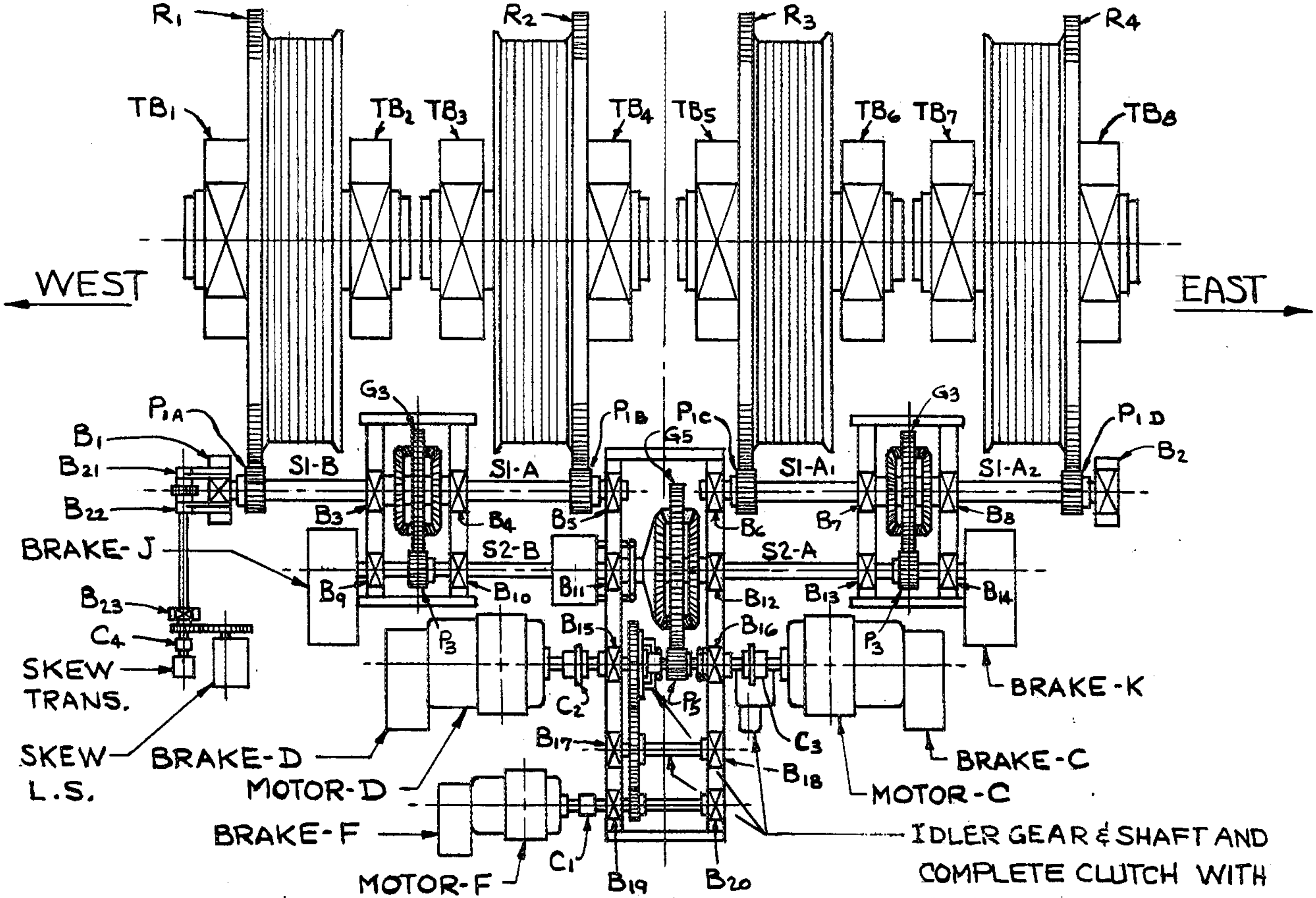


SOUTH TOWER DRIVE

TABLE 5

SOUTH TOWER

GEAR IN QUESTION				GEAR TOOTH MEASUREMENTS						WEAR		BACKLASH	
							Present Measurements						
							Position on Tooth Measurement Taken						
Gear	Circular Pitch (CP) ~~or Diametral Pitch (DP)~~	Number of Teeth in Gear	Pressure Angle in Degrees	Type of Measurement Span or Chordal Tooth Thickness	For Span - Number of Teeth Span Taken Over	"As Built" Measurement	EAST	MIDDLE	WEST	Inches	Percent of Original Tooth Thickness	Present	Original
G_5	1.50	120	20	Span	17	24.073		24.073		.062	8.3	1/32	
P_5	1.50	19		Span	3	3.653	3.642	3.640	3.369	.014	1.9		
G_3-West	1.75	80		Span	11	17.891	17.824	24	21	.070	8.0	1/32	
P_3-West	1.75	21		Span	3	4.275	4.261	56	55	.020	0.6		
G_3-East	1.75	80		Span	11	17.891	17.837	39	40	.054	6.2	3/64	
P_3-East	1.75	21		Span	3	4.275	4.255	54	52	.023	1.3		
R_4	2.25	280		Chordal		1.125	1.105	11	12	.020	0.2	3/64	
P_1D	2.25	19		Span	3	5.476	5.419	5.419	5.419	.057	5.1		
R_3	2.25	280		Chordal		1.125	1.108	12	09	.016	1.4	3/64	
P_1C	2.25	19		Span	3	5.476	5.416	5.419	5.421	.060	5.3		
R_2	2.25	280		Chordal		1.125	1.132	34	29	NIL		1/32	
P_1B	2.25	19		Span	3	5.476	5.425	5.425	5.423	.053	4.7		
R_1	2.25	280		Chordal		1.125	1.111	12	12	.014	1.2	3/64	
P_1A	2.25	19		Span	3	5.476	5.420	5.424	5.428	.056	5.0		

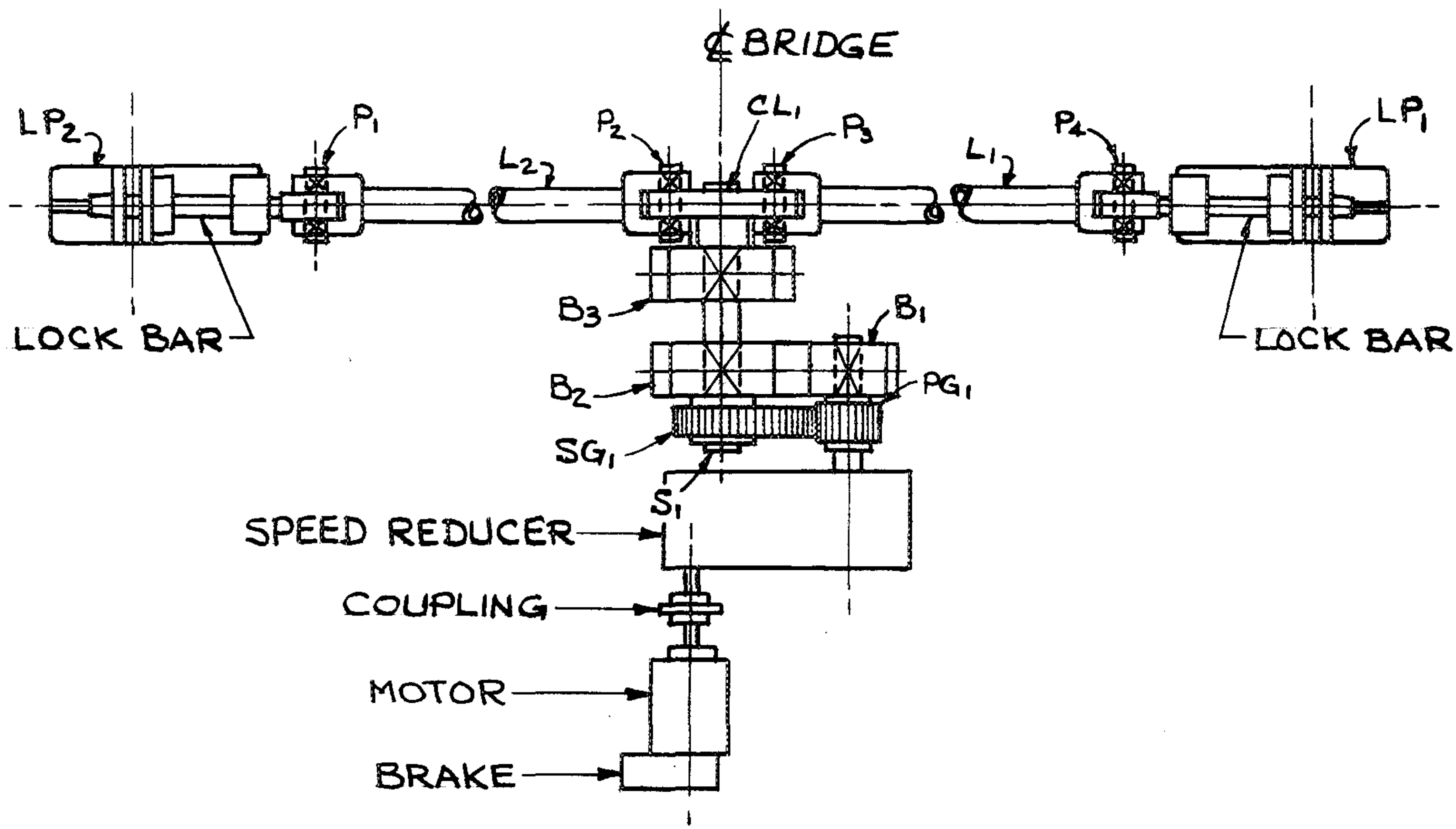


SOUTH TOWER DRIVE

TABLE 6

SPAN DRIVE COMPONENTS
SOUTH TOWER

PART NAME	#	REMARKS
BRAKE	C	Shoes are in firm contact. Limit switch inoperable. Thruster fluid OK. Gap = 1 5/8".
BRAKE	D	Limit switch inoperable. Thruster fluid level OK. Drum not well polished, but smooth. No signs of distress. Gap = 1 1/2".
BRAKE	F	(For emergency motor not currently in operation.) Fluid level OK. Drum rusty, paint on it. South shoe not in good contact with drum. Brake shoes are out of adjustment. Has no limit switch. Gap = 15/16".
BRAKE	J	Brake shoes in firm contact with drum. Drum well polished. Limit switch for hand release doesn't trip when brake released manually. (Limit switch inoperable.) Thruster overfilled with fluid. Gap = 2 1/4".
BRAKE	K	Limit switch moves, but operation questionable. Drum nicely polished. Fluid level overfull. Gap = 2 5/16".
COUPLING	C_1	Opened - Inadequate lubricant. No other deficiencies found.
COUPLING	C_2	Opened - Lubricant OK. No other deficiencies found.
COUPLING	C_3	Opened - Lubricant OK. No other deficiencies found.



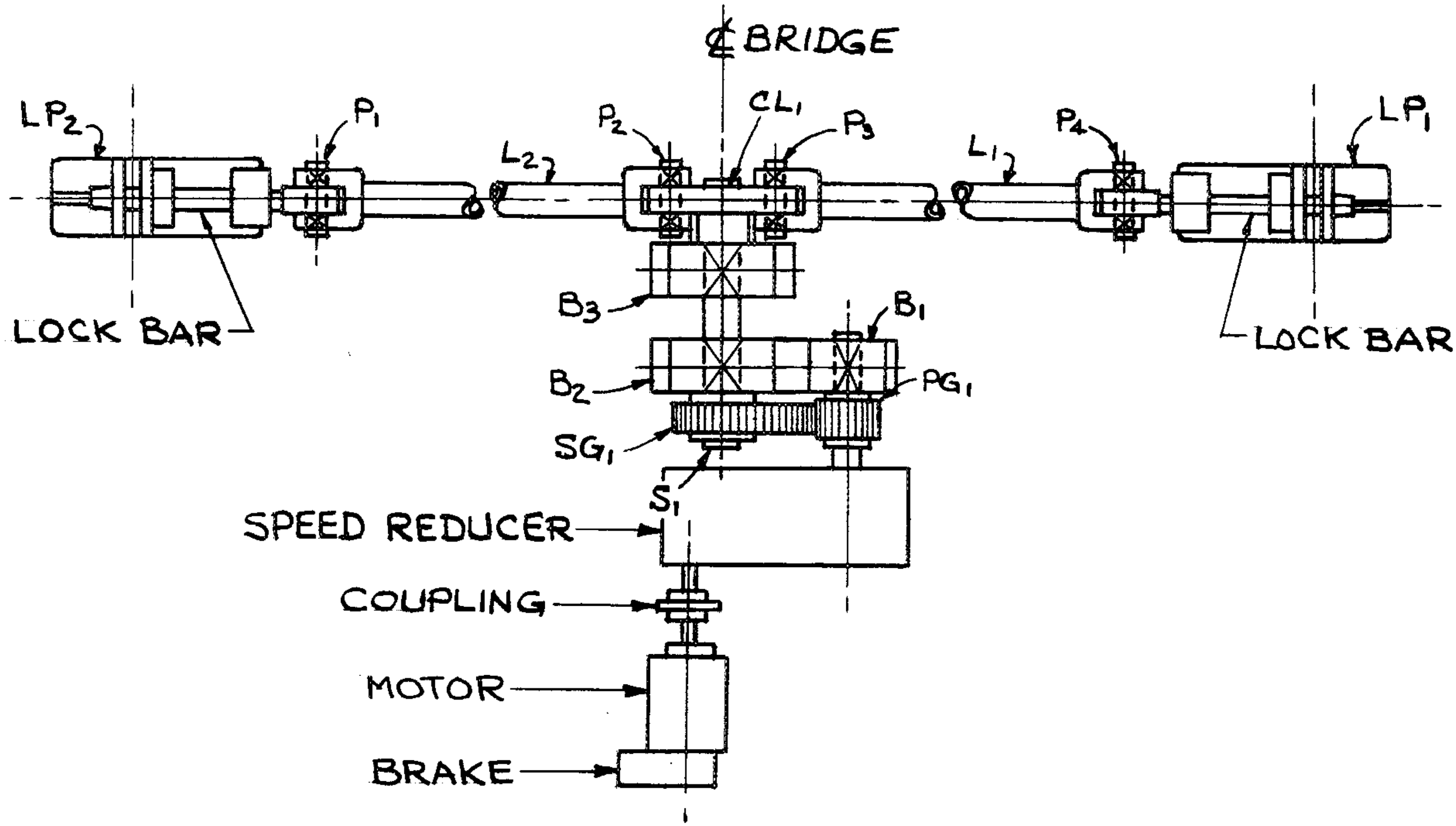
LOWER SPAN LOCK

LOWER SPAN LOCK

TABLE 7

NORTH

PART NAME	PART #	REMARKS
BRAKE		Mounting bracket severely corroded.
MOTOR COUPLING		Opened - All internal parts heavily corroded. No lubricant present. Grid fractured.
SPEED REDUCER		Opened - Oil in housing heavily contaminated. Much foreign matter and sludge in bottom of housing and in oil passages. Seal leaks on input shaft.
PINION	PG_1	Teeth on both gears have experienced severe loss of metal due to corrosion.
GEAR	SG_1	Was not being lubricated until recently.
BEARING	B_1	Clearance .008".
BEARING	B_2	Clearance .012". Nuts on cap bolts heavily corroded.
BEARING	B_3	Clearance .012".
CONNECT ROD	L_1	Bolts and nuts used to attach clevis at each end heavily corroded.
CONNECT ROD	L_2	Bolts and nuts used to attach clevis at each end heavily corroded.
PIN	P_1	Clearance .009".
PIN	P_2	Clearance .007".
PIN	P_3	Clearance .010".
PIN	P_4	Clearance .010".



LOWER SPAN LOCK

TABLE 8

LOWER SPAN LOCK

SOUTH

PART NAME	PART #	REMARKS
BRAKE		Mounting bracket severely corroded.
MOTOR COUPLING		Opened - All parts heavily corroded. No lube.
SPEED REDUCER		Opened - Oil heavily contaminated. Bottom of reducer housing and oil passages full of debris and sludge.
PINION	PG_1	Pinion and gear both experienced heavy loss of metal due to corrosion. Was not being lubricated until recently.
GEAR	SG_1	Span over 7 teeth 9.440" at south end. Loss of .103" on tooth thickness or 13.8%.
BEARING	B_1	Nuts on mounting bolts severely corroded.
BEARING	B_2	Nuts on cap bolts severely corroded.
BEARING	B_3	Nuts on cap bolts severely corroded. Head on mounting bolt severely corroded.
CONNECT ROD	L_1	Bolts and nuts attaching east clevis moderately corroded.
CONNECT ROD	L_2	Bolts attaching west clevis heavily corroded. Pipe heavily corroded.
PIN	P_1	
PIN	P_2	
PIN	P_3	
PIN	P_4	
GUIDE & SOCKET	LP_1	Anchor bolts heavily corroded.
CASTINGS	LP_2	Anchor bolts and nuts heavily corroded.

COUNTERWEIGHT ROPES VIBRATION TEST

NORTH TOWER

TABLE 9

PART NAME	#	SECONDS FOR 30 VIBRATIONS	PART NAME	#	SECONDS FOR 30 VIBRATIONS
WIRE ROPE	1	20	WIRE ROPE	#26	20
	2	19		27	18
	3	20		28	19
	4	20		29	21
	5	20		30	20
	6	20		31	20
	7	20		32	20
	8	20		33	21
	9	20		34	20
	10	19		35	19
	11	20		36	20
	12	20		37	20
	13	20		38	20
	14	19		39	20
	15	18		40	20
	16	17			
	17	18			
	18	18			
	19	19			
	20	18			
	21	20			
	22	20			
	23	20			
	24	18			
	25	20			

- AVERAGE = 19.525 OR 92.2 VIB/MINUTE
- MAXIMUM VARIATION - 4 SECONDS FOR 30 VIBRATIONS OR 23.5%
- DIFFERENCE BETWEEN TWO ENDS OF LIFT SPAN IS 92.4 - 92.2 = .2 VIB/MINUTE OR 0.2%
- MAXIMUM DIFFERENCE IN TENSION = 52.5%

COUNTERWEIGHT ROPES VIBRATION TEST

TABLE 10

SOUTH TOWER

PART NAME	#	SECONDS FOR 30 VIBRATIONS	PART NAME	#	SECONDS FOR 30 VIBRATIONS
WIRE ROPE	1	22	WIRE ROPE	#26	19
	2	20		27	19
	3	20		28	18
	4	20		29	19
	5	20		30	19
	6	21		31	19
	7	20		32	21
	8	20		33	20
	9	20		34	21
	10	20		35	19
	11	19		36	20
	12	19		37	20
	13	18		38	19
	14	17		39	20
	15	20		40	20
	16	18			
	17	19			
	18	19			
	19	20			
	20	19			
	21	19			
	22	19			
	23	18			
	24	18			
	25	21			

- AVERAGE = 19.475 OR 92.4 VIB/MINUTE
- MAXIMUM VARIATION - 5 SECONDS FOR 30 VIBRATIONS OR 29.4%
- DIFFERENCE BETWEEN TWO ENDS OF LIFT SPAN IS 92.4 - 92.2 = .2 VIB/MINUTE OR 0.2%
- MAXIMUM DIFFERENCE IN TENSION = 67.4%

PART V-6

INSTRUMENTATION INVESTIGATIONS

PART V-6 - INSTRUMENTATION INVESTIGATIONS

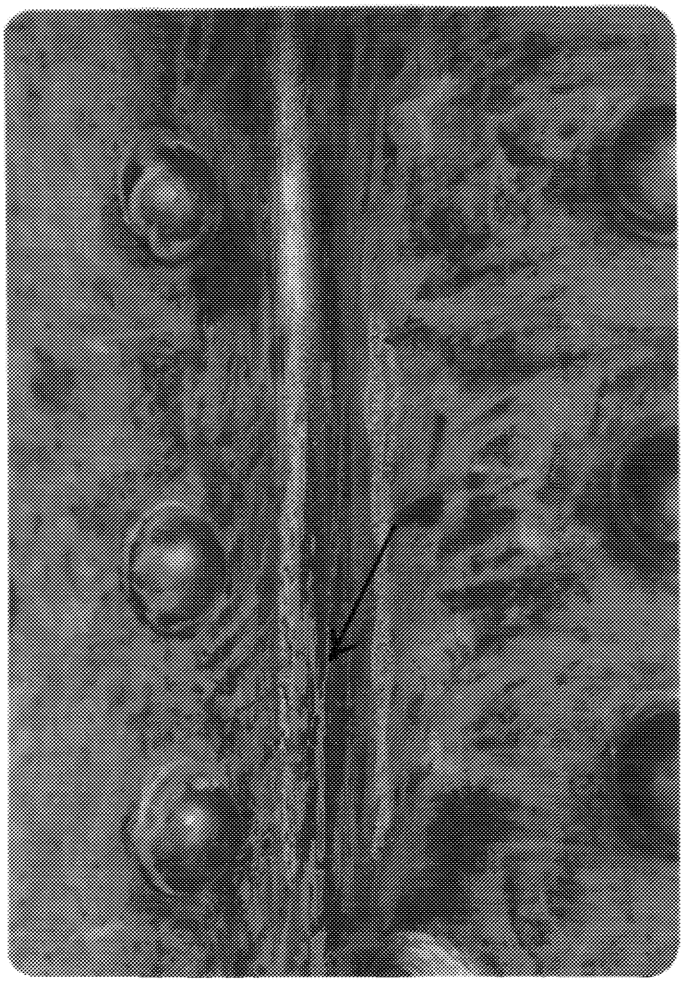
The Consultant engaged the services of two sub-consultants specialized in their field to perform two separate investigations on the structure. The first performed non-destructive testing on several connections of the lift span and approach spans and the second recorded and analyzed vibration measurements on the lift span and towers. The results of these investigations are presented herein.

Non-Destructive Testing

Two typical floorbeam connections on the lift span and one stringer connection in each approach span were examined by magnetic particle inspection for possible fatigue cracks or other metalwork defects. Inspection and maintenance experience with railroad bridges has revealed fatigue problems at floorbeam and stringer connections. The west truss floorbeam connection at Panel Point 3 and the east truss floorbeam connection at Panel Point 8 were tested in the lift span. The two remaining checks were made at the east stringer connection and the west stringer connection at Panel Point 4 of the respective north and south approach spans. These two stringer connections were selected because of the maximum impact of loadings moving from the approaches onto the spans.

All the connections were prepared for testing by removing the finish paint cover and most of the primer with a burning torch or power brush. The top 18 inches of the fillets and both legs of the connection angles were cleaned. At the floorbeam connections, an additional area one foot high above the top of the floorbeam was cleaned on the gusset plate.

A portable electric magnaflux machine with gray iron particles was utilized for the testing (see Photographs II-52 and 53). The angles, plates and rivets of all the connections are in good structural condition. A minor defect was noted in the fillet of the west stringer connection angle at Panel Point 4 of the south approach span (see Photograph II-54). A 6 to 7 inch long linear indication was detected in the fillet as shown in Photograph I-35). The separation appeared to be only a small overlap or build-up of metal created during rolling of the angle. There was no indications of relative movement along the surfaces of the crack, or rust emitting as is common in a fatigue crack. No repairs are required. The metalwork of all the connections was prime and finish coated with paint shortly after the testing. The subconsultant's report for the non-destructive testing is included as Appendix C of this report.



Photograph I-35 - Minor imperfection in fillet of west stringer connection angle at Panel Point 4, south approach span.

Vibration Measurements

Vibration measurements were recorded on the bridge at Panel Points L3', L9, and L3 on the lift span on June 6 and 7, 1984. Measurements were recorded on June 6, 1984 during the crossing of a coal train and on June 7, 1984 during the crossing of two passenger trains.

Vibrations induced on the north and south towers as a result of raising and/or lowering the lift span were also recorded.

The vibration measurements were recorded at the same locations as the measurements recorded on September 7 and 8, 1971 during a previous inspection. The 1971 and the 1984 measurements are compared in this report.

As in the 1971 study, vibration measurements were recorded using Sprengnether Instrument Company's portable Engineering Seismographs. The instruments measured three orthogonal components (2 horizontal and 1 vertical). Three instruments were used for the study. Two of the instruments recorded displacement and the third instrument recorded velocity. As in the 1971 study, the instruments were placed directly on the top flange of the floorbeams outside the walkway at the three panel points. For the tower measurements, the instruments were placed directly on the concrete floor in the machinery room at each tower top.

Maximum displacements and their corresponding frequencies at the five recording locations are as follows:

Panel Point L3'

Displacement (IN)	Frequency (HZ)
0.01-0.02 Longitudinal	1-2
0.01-0.02 Transverse	1-3
0.03-0.04 Vertical	1-2

Panel Point L9

Displacement (IN)	Frequency (HZ)
0.008-0.009 Longitudinal	1-2
0.02-0.03 Transverse	1-2
0.02-0.03 Vertical	1-2

Panel Point L3

Displacement (IN)	Frequency (HZ)
0.001-0.002 Longitudinal	8-10
0.005-0.006 Transverse	4-5
0.003-0.006 Vertical	7-8

North Tower

Displacement (IN)	Frequency (HZ)
.005-.006 Longitudinal	3-4
.02-.03 Transverse	1-2
.002-.003 Vertical	2-3

South Tower

Displacement (IN)	Frequency (HZ)
0.03-0.04 Longitudinal	0.7-0.8
0.01-0.02 Transverse	1-2
0.005-0.006 Vertical	1-2

All of the aforelisted maximum displacements are very small and well within the allowable deflections permitted by the American Railway Engineering Association Specifications for Steel Railway Bridges. As was also concluded in the 1971 report, the lift span and the towers are very stiff structures. The recorded displacements of the lift span during the crossing of trains and recorded displacements of the towers during the raising and lowering of the lift span are inconsequential, and should be of no concern to the U. S. Army Corps of Engineers or the current users of the bridge.

It is noted that Weston Geophysical Corporation re-examined and re-interpreted their 1971 peak displacement values at Panel Point L9 on the lift span and at the top of the south tower. The re-interpreted displacements are in closer agreement with the displacements recorded for this inspection report.

The complete text of the Weston Geophysical Corporation's report is included as Appendix D of this report.

PART V-7

EVALUATION OF LOADS AND STRESSES

PART V-7 - EVALUATION OF LOADS AND STRESSES

Loading

Dead Load

The Inspection and Condition Report dated January, 1972 stated that there have been only small increases in the dead load since the construction of the bridge. The rating stresses calculated for that report reflected very small increases in dead load. The increase in dead load resulted in increases of chord dead load stresses between .4% and .5%.

During the field inspection performed between April 30 and May 18, 1984, no significant modifications were observed to have been made on the bridge that would result in increases in dead loading over that cited in the January, 1972 Condition and Inspection Report. It was noted that NASA experimental equipment, reported to be added to the lift span trusses in the January, 1972 Condition and Inspection Report, has been removed.

Live Load

The original design was made for a Cooper E60 railroad live loading and a 14 inch railway artillery, as shown on the original lift span stress sheet. The January, 1972 Condition and Inspection Report stated that the bridge was subjected, at that time, to a maximum live loading of Cooper E35, without hammer blow. Investigation of the use of the bridge reveals that the bridge is now subjected to live loadings greater than Cooper E35.

Mr. Michael Schmidt of the Bay Colony Railroad Corporation provided the following information regarding their freight operations.

The Bay Colony Railroad Corporation currently runs two loaded freight trains per week to the Cape and two empty freight trains per week from the Cape. The railroad logs reveal that the yearly average number of freight cars per train is eight. Most of the freight cars are loaded with lumber, coal, liquefied petroleum gas (LPG) and packaging plastic. The gross weight of these freight cars is:

Lumber Car - 190,000 lbs.

LPG Tank Car - 190,000 lbs.

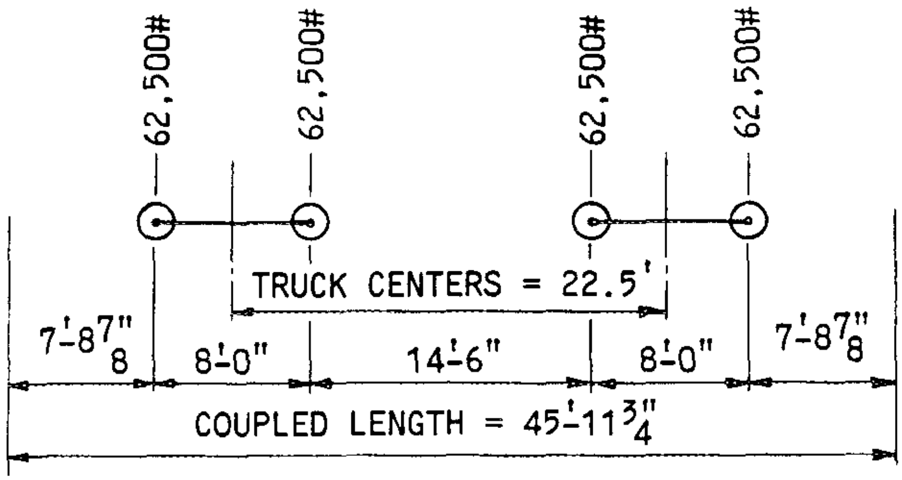
Coal Hopper Car - 240,000 lbs.

The freight cars carrying packaging plastic have a gross weight of only slightly more than their tare weight. One hundred to one hundred and twenty (100-120) coal carrying hopper cars per year are delivered to Otis Air Force Base. The coal trains average 10 hopper cars per train and are pulled over the bridge at a speed of 5 miles per hour (see Photograph I-36). Coal is delivered to Otis Air Force Base during the spring of the year with additional shipments, if required, delivered during autumn months.

Photograph I-36 - Coal train crossing span.

The summarized shipping information translates into an average of 10-12 loaded coal trains per year. Of a total of 104 loaded freight trains per year, the loaded coal trains represent only 9.6% to 11.5%, or an average of 10% of the loaded freight trains crossing the bridge. The cars used to carry coal are similar to Southern Railway System Standard Hopper Car Number 352622 with a gross weight of 263,000 pounds. This information was provided by Mr. Reed H. Potter of the Maine Central Railroad Company. Mr. Potter served as a private consultant to the Bay Colony Railroad Corporation. The coupler-to-coupler length, and axle spacing for the hopper car are shown in Figure 7-1. (Dimensions obtained via telephone from Southern Railway Systems.)

125 TON ALCO S2, S3 & S4
DIESEL ELECTRIC LOCOMOTIVES



SOUTHERN RAILWAY SYSTEM
STANDARD HOPPER NO. 352622
263000 LBS. GROSS WEIGHT
(65,750 LBS. PER AXLE)

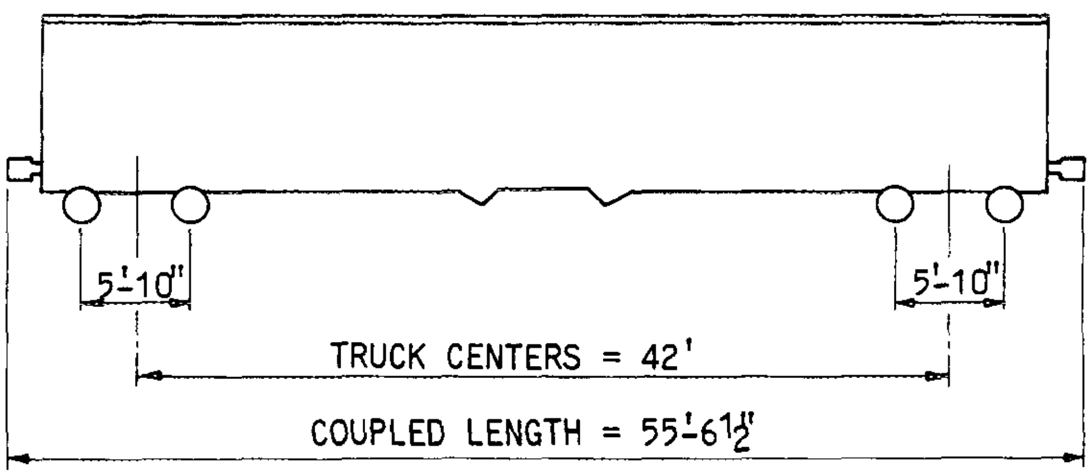


FIGURE 7-1

Mr. Schmidt also stated that the Bay Colony Railroad Corporation currently owns and operates one Alco S2 and five Alco S4 diesel-electric locomotives. The gross weight of these locomotives varies from 115 to 125 tons. Figure 7-1 shows the axle loads and axle spacing for these locomotives.

The Cape Cod and Hyannis Railroad, Inc. currently runs eight trains daily over the bridge between mid-April and October. Mr. Peter Verges of the Cape Cod and Hyannis Railroad, Inc. stated that the Railroad currently owns and operates two GP9's and one Alco S3 diesel-electrical locomotives. These locomotives are used primarily to move passenger cars, which have an average gross weight between 70 and 90 tons. The passenger cars are 79 feet long between couplers and are supported on two 3 axle trucks.

Wind Load

The original design wind loads were in accordance with the 1931 AREA General Specifications for Steel Railway Bridges and the 1922 AREA Specifications for Movable Bridges. For the January, 1972 Condition and Inspection Report, the bridge was analyzed in accordance with the 1970 AREA Specifications for Steel Railway Bridges. For this report, the bridge was not reanalyzed for wind loading, because the design criteria for wind loading specified in the current 1983 AREA Specifications for Steel Structures is not significantly different from the criteria for wind loading specified in the 1970 AREA Specifications for Steel Railway Bridges.

Stresses

The original design allowable stresses were in accordance with the 1931 AREA General Specifications for Steel Railway Bridges and the 1922 AREA Specifications for Movable Bridges. For the January, 1972 Condition and Inspection Report, the stresses were reviewed on the basis of the 1970 AREA Specifications for Steel Railway Bridges.

For strength analysis and rating, there is no significant difference between the 1970 AREA Specifications for Steel Railway Bridges and the current 1983 AREA Specifications for Steel Structures. However, one of the significant differences between the two specifications is the fatigue requirements for members and connections subjected to repeated fluctuations of stress. This report includes a fatigue analysis of the members subjected to repeated fluctuations of stress in accordance with Chapter 15, Part 1, Article 1.3.13 - Fatigue; and Part 7, Article 7.3.4.2 - Fatigue, of the 1983 AREA Specifications.

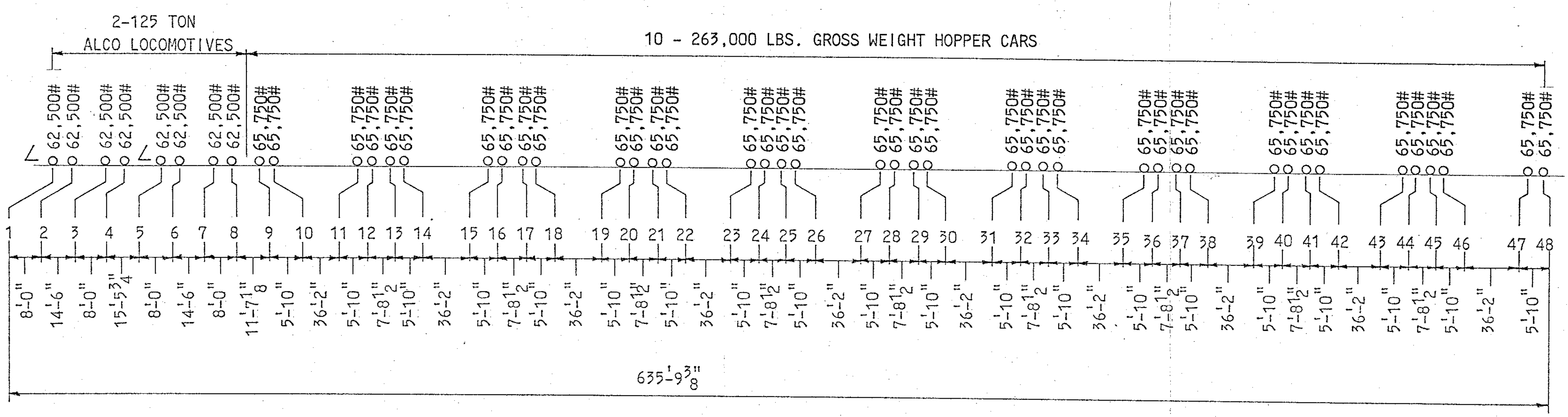
Analysis

This report presents the results of an analysis of the bridge for current design loads in accordance with the 1983 AREA Specifications for Steel Structures.

The bridge members have been rated in accordance with Chapter 15, Part 7 - Existing Bridges, Section 7.3 - Rating. For the rating, the original dead load member forces were used. The differences between the original dead load member forces and the current dead load member forces is pendantic and thus, inconsequential to the rating of the bridge as a whole. The members have been rated for both full impact and in accordance with Article 1.3.5 and reduce impact load in accordance with Article 7.3.3.3 for a speed of 10 MPH.

Fatigue stress ranges have been computed for all members subjected to repeated fluctuations of stress, due to live loading. Stress ranges have been computed for members for the following live loads:

1. Cooper E80
2. Cooper E60
3. Cooper E35
4. Bay Colony Railroad Typical Train with full impact (see Figure 7-2)
5. Bay Colony Railroad Typical Train with reduced impact - 10 mph
6. Bay Colony Railroad Coal Train with full impact (see Figure 7-3)
7. Bay Colony Railroad Coal Train with reduced impact - 10 MPH



BAY COLONY RAILROAD COAL TRAIN

FIGURE 7-2

Fatigue Strength

The major factors governing fatigue strength are number of stress cycles, the magnitude of the stress range and the type and location of constructional details. Each of these three items as they relate to the Buzzards Bay Railroad Bridge are herein discussed.

Stress Cycles

In the absence of traffic surveys or other information, the number of constant stress cycles, N to be considered for the design and analysis of railroad bridges is selected from Table 1.3.13A of the 1983 AREA Specifications. The number of constant stress cycles subsequently determine the allowable fatigue stress range for members and connections as shown in Table 1.3.13A - Other than Fracture Critical Members and Table 1.14.11 - Fracture Critical Members. The parameters used to develop Tables 1.3.13A and 1.3.13 are shown in Table 9.1.13A and reflect traffic densities that greatly exceed past, existing and projected traffic densities for the Buzzards Bay Railroad Bridge. Table 9.13.13A assumes 60 daily trains and each train averages 60 load units (cars or engines).

In the absence of traffic surveys for the Buzzards Bay Railroad Bridge, past traffic densities may be related to number of lift span closings (lowerings). The lift span was put into operation on December 27, 1935. As of June 13, 1984, the bridge operator's log recorded that the lift span had been lowered 136,514 times. If it assumed that 20% of these lowerings were for maintenance, approximately 109,217 trains have transversed the lift span since its opening. Over this 48.5 year period, the traffic density averaged 6.2 trains per day, which is approximately one-tenth of the daily traffic of 60 trains per day listed in Table 9.1.3.13A.

Existing traffic densities may be computed using information previously discussed.

Freight Trains Per Day

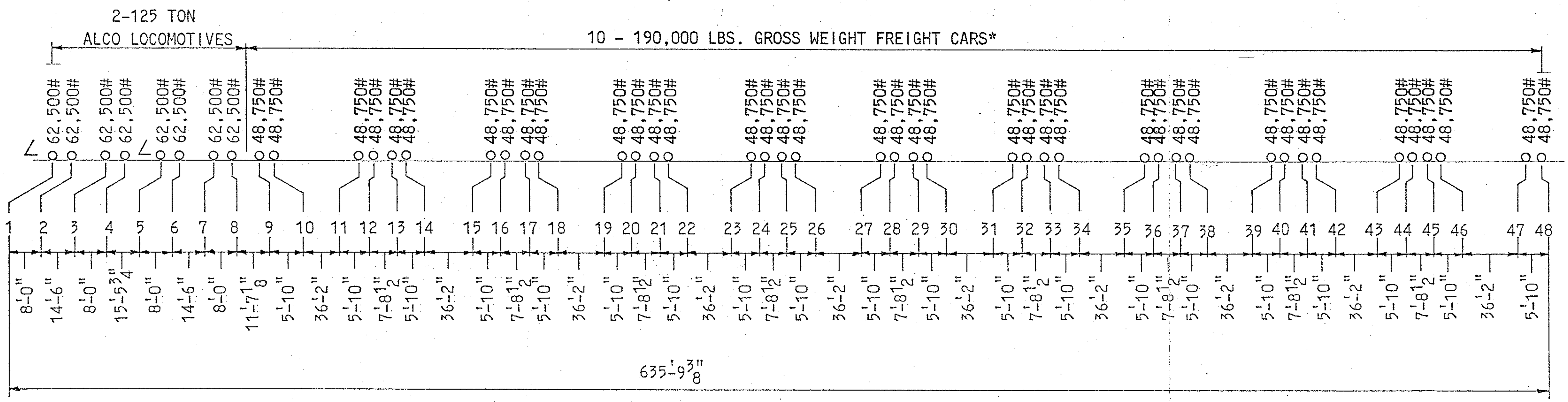
2 Trains per Week x 2 Crossings/7 Days	=	0.57 Trains

Passenger Trains Per Day

4 Trains per Day x 2 Crossings x 200 Days/365	=	4.38 Trains
Total Daily Trains (Crossings)	=	4.95

This existing average daily traffic is one-twelfth of daily traffic listed in Table 9.1.3.13A. Also, existing freight trains average only 12 load units per train versus 60 load units specified in Table 9.1.3.13A.

Considering the geography, demography, recreational/tourism interests, and the two automotive vehicular alternative accesses to Cape Cod, it is highly improbable that train traffic to Cape Cod will increase significantly. If there would be any increase, it would be an increase in the number of passenger trains, rather than an increase in freight trains. For purposes of this report, it is assumed that future traffic density over the Buzzards Bay Railroad Bridge will be identical to the existing traffic density of 4.95 trains per day.



BAY COLONY RAILROAD TYPICAL TRAIN

*ASSUME TYPICAL FREIGHT CARS HAVE SAME LENGTH
AND AXLE SPACING AS HOPPER COAL CARS

FIGURE 7-3

Using the aforementioned traffic densities modified numbers of occurrences of constant stress cycles N which would cause fatigue damage equivalent to the fatigue damage caused by a larger number of variable stress cycles, resulting from actual traffic densities is computed. The modified constant stress cycles are computed for an assumed 100 year bridge life to year 2035. For a bridge life of 100 years, the assumed number of trains is:

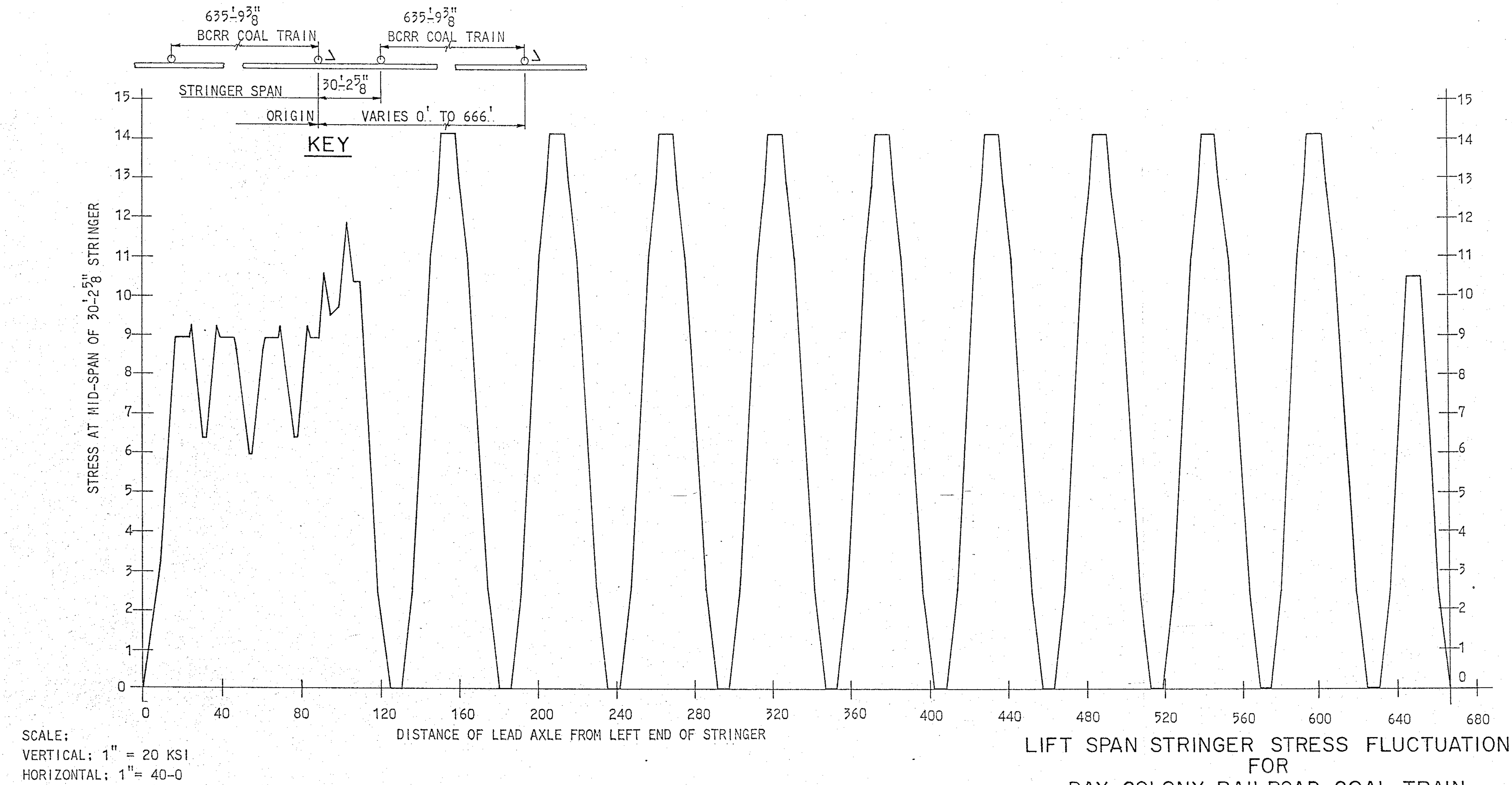
Period	Years	Trains/Day	Total Trains
1935-1984	48.5	7	123,918
1984-2035	51.5	5	93,988
	100.0		217,906
			Say 220,000

MODIFIED AREA TABLE 9.1.3.13A PARAMETERS - BUZZARDS BAY RAILROAD BRIDGE

Member Classification	Span Length Track Load	Trains in 100 Years	Stress Cycles per Train	N_v	N/N_v	N
Truss Chord Members	L >100'	220,000	2	440,000	0.045	20,000
Stringers	50' > L >30'	220,000	12[a]	2,640,000	0.081	220,000
Truss Web Members	1 Track Loaded	220,000	2	440,000	0.113	50,000
Floorbeams and Hangers	1 Track Loaded	220,000	12[a]	2,640,000	0.097	260,000

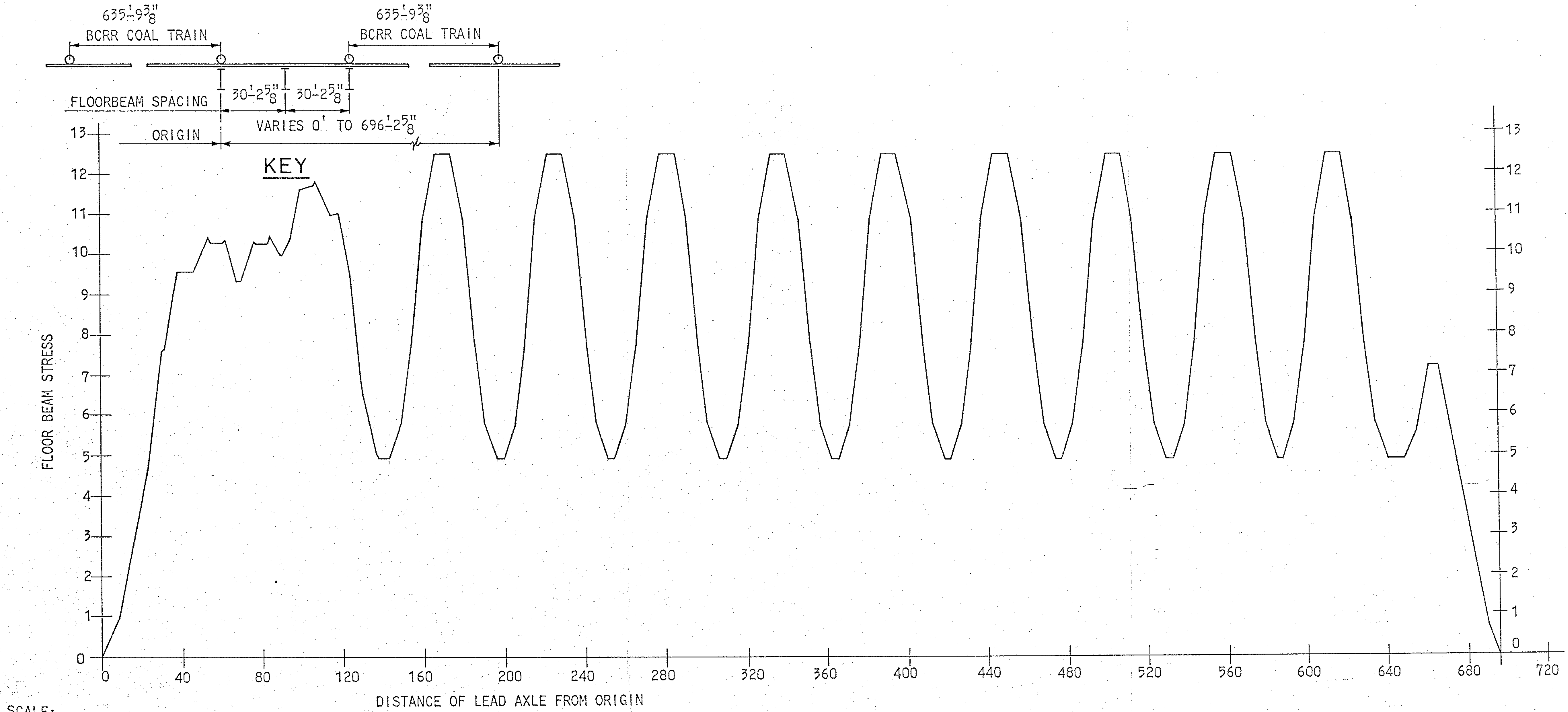
[a] Based on one cycle per car or engine for modified train averaging 12 load units. See Figures 7-4, 7-5 and 7-6 for plot of stress fluctuation in stringers, hangers and floorbeams.

N/N_v Ratio used in AREA Table 9.1.3.13A. A conservative ratio that is used for simplicity of computations.



LIFT SPAN STRINGER STRESS FLUCTUATION
FOR
BAY COLONY RAILROAD COAL TRAIN

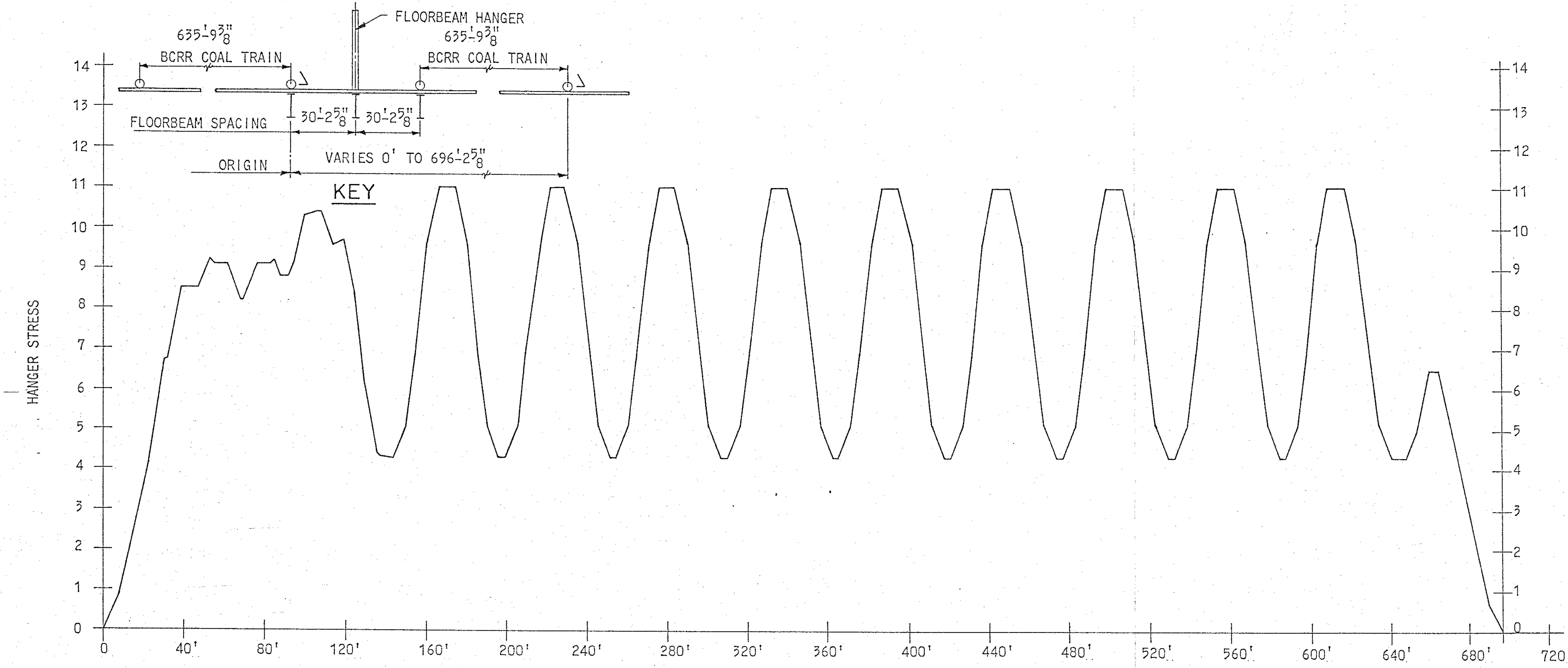
FIGURE 7-4



SCALE:
VERTICAL: 1" = 20 KSI
HORIZONTAL: 1" = 40'-0"

LIFT SPAN FLOORBEAM STRESS FLUCTUATION
FOR
BAY COLONY RAILROAD COAL TRAIN

FIGURE 7-5



DISTANCE OF LEAD AXLE FROM ORIGIN

SCALE:
VERTICAL: 1" = 20 KSI
HORIZONTAL: 1" = 40'-0"

LIFT SPAN HANGER STRESS FLUCTUATION
FOR
BAY COLONY RAILROAD COAL TRAIN

FIGURE 7-6

BUZZARDS BAY RAILROAD LIFT BRIDGE

LIFT SPAN FATIGUE STRESS RANGE (KSI)

Member	E80 Full	E60 Full	E35 Full	BCRR-Typical Full	BCRR-Typical Red	BCRR-Coal Full	BCRR-Coal Red	Allowable AREA	Allowable Modified
U0-U2	-	-	-	-	-	-	-	-	-
U2-U4	-	-	-	-	-	-	-	-	-
U4-U6	-	-	-	-	-	-	-	-	-
U6-U8	-	-	-	-	-	-	-	-	-
U8-U9	-	-	-	-	-	-	-	-	-
L1-L3	14.3	10.7	6.2	6.5	5.8	8.1	7.2	20	37
L3-L5	14.4	10.8	6.3	6.5	5.8	8.3	7.3	20	37
L5-L7	14.1	10.6	6.2	6.3	5.6	8.3	7.3	20	37
L7-L9	14.2	10.6	6.2	6.3	5.6	8.3	7.4	20	37
U0-L1	16.4	12.3	7.2	7.5	6.6	9.2	8.2	14	28
L1-U2	-	-	-	-	-	-	-	-	-
U2-L3	17.8	13.35	7.8	8.3	7.3	9.9	8.7	14	28
L3-U4	-	-	-	-	-	-	-	-	-
U4-L5	21.0	15.7	9.2	10.0	8.8	11.6	10.2	14	28
L5-U6	-	-	-	-	-	-	-	-	-
U6-L7	26.1	19.6	11.4	12.5	11.0	14.2	12.5	14	28
L7-U8	20.1	15.1	8.8	9.6	8.5	10.9	9.6	14	28
U8-L9	23.6	17.7	10.3	11.3	9.9	12.8	11.3	14	28
U0-L0	-	-	-	-	-	-	-	-	-
U1-L1	-	-	-	-	-	-	-	-	-
U3-L3	-	-	-	-	-	-	-	-	-
U5-L5	-	-	-	-	-	-	-	-	-
U7-L7	-	-	-	-	-	-	-	-	-
U9-L9	-	-	-	-	-	-	-	-	-
U2-L2 U4-L4 U6-L6 U8-L8	14.3	10.8	6.3	7.5	5.9	8.4	6.6	7	19
Stringers	21.5	16.1	9.4	10.2	8.2	14.2	11.4	10	21
Floorbeams	21.3	16.0	9.3	11.1	8.7	12.5	9.8	7	19

BCRR - Denotes Bay Colony Railroad

Full - Denotes stress range, including live load with impact applied in accordance with AREA Article 1.3.5.

Red - Denotes stress range, including live load with impact applied in accordance with AREA Article 1.3.5, but reduced for a speed of 10 mph in accordance with AREA Article 7.3.3.3.

Stresses for hangers are for combined axial tension and bending.

BUZZARDS BAY RAILROAD LIFT BRIDGE

TOWER SPAN FATIGUE STRESS RANGE (KSI)

Member	E80 Full	E60 Full	E35 Full	BCRR-Typical Full	BCRR-Typical Red	BCRR-Coal Full	BCRR-Coal Red	Allowable AREA	Allowable Modified
U0-U1	-	-	-	-	-	-	-	-	-
U1-U2	-	-	-	-	-	-	-	-	-
U2-U3	-	-	-	-	-	-	-	-	-
U3-U4	-	-	-	-	-	-	-	-	-
L0-L1	3.3	2.5	1.4	-	-	1.8	1.6	20	37
L1-L2	5.1	3.8	2.2	-	-	2.8	2.4	20	37
L2-L3	6.0	4.5	2.6	-	-	3.3	2.9	20	37
L3-L4	4.4	3.3	1.9	-	-	2.5	2.1	20	37
U0-L1	4.7	3.6	2.1	-	-	2.7	2.3	14	28
L0-U1	-	-	-	-	-	-	-	-	-
U1-L2	6.1	4.5	-	-	-	3.2	-	14	28
L1-U2	5.0	3.7	2.2	-	-	2.5	2.2	14	28
U2-L3	-	-	-	-	-	-	-	-	-
L2-U3	5.7	4.3	2.5	-	-	3.2	2.8	14	28
U3-L4	-	-	-	-	-	-	-	-	-
L3-U4	7.0	5.2	3.1	-	-	3.9	3.4	14	28
U0-L0	-	-	-	-	-	-	-	-	-
U1-L1	-	-	-	-	-	-	-	-	-
U2-L2	3.7	2.8	1.6	-	-	2.1	1.8	14	28
U3-L3	4.0	3.0	1.7	-	-	2.4	2.0	14	28
U4-L4	-	-	-	-	-	-	-	-	-
Stringers	22.2	16.7	9.7	-	-	14.7	11.7	10	21
Floorbeams	21.7	16.3	9.5	-	-	12.4	9.7	7	19

BCRR - Denotes Bay Colony Railroad

Full - Denotes stress range, including live load with impact applied in accordance with AREA Article 1.3.5.

Red - Denotes stress range, including live load with impact applied in accordance with AREA Article 1.3.5, but reduced for a speed of 10 mph in accordance with AREA Article 7.3.3.3.

BUZZARDS BAY RAILROAD LIFT BRIDGE

LIFT SPAN COOPER E RATING

Member	Strength Rating	Fatigue Rating AREA	Fatigue Rating Modified
U0-U2	202	-	-
U2-U4	112	-	-
U4-U6	114	-	-
U6-U8	114	-	-
U8-U9	114	-	-
L1-L3	115	111	206
L3-L5	112	111	205
L5-L7	114	113	209
L7-L9	113	112	208
U0-L1	95	68	136
L1-U2	86	-	-
U2-L3	97	63	125
L3-U4	84	-	-
U4-L5	102	53	106
L5-U6	81	-	-
U6-L7	110	43	85
L7-U8	118	55	111
U8-L9	135	47	94
U0-L0	1009	-	-
U1-L1	-	-	-
U3-L3	-	-	-
U5-L5	-	-	-
U7-L7	-	-	-
U9-L9	-	-	-
U2-L2	112	38	105
U4-L4	112	38	105
U6-L6	112	38	105
U8-L8	112	38	105
Stringers	112	37	78
Floorbeams	109	25	70

BUZZARDS BAY RAILROAD LIFT BRIDGE

TOWER SPAN COOPER E RATING

Member	Strength Rating	Fatigue Rating AREA	Fatigue Rating Modified
U0-U1	502	-	-
U1-U2	237	-	-
U2-U3	199	-	-
U3-U4	600	-	-
L0-L1	461	>80	>80
L1-L2	274	>80	>80
L2-L3	246	>80	>80
L3-L4	379	>80	>80
U0-L1	288	>80	>80
L0-U1	281	-	-
U1-L2	423	>80	>80
L1-U2	605	>80	>80
U2-L3	439	-	-
L2-U3	293	>80	>80
U3-L4	195	-	-
L3-U4	216	>80	>80
U0-L0	4,944	-	-
U1-L1	24,733	-	-
U2-L2	564	>80	>80
U3-L3	473	>80	>80
U4-L4	360	-	-
Stringers	81	36	75
Floorbeams	80	25	70

Constructional Details

All of the members investigated for fatigue stresses on the Buzzards Bay Railroad Bridge are classified under the General Condition - Mechanically Fastened Connections, and under the Situation - Base Metal at Net Section of Riveted Connections, and thus are subjected to the requirements of Stress Category D.

Stress Range

The modified allowable fatigue stress range for the modified number of constant stress cycles, N for Stress Category D are computed by straight line interpolation (extrapolation) between allowable fatigue stress range values for 150,000 and 2,000,000 constant stress cycles. Modified values are computed for other than fracture-critical members and for fracture-critical members. The modified allowable fatigue stress range values for the Buzzards Bay Railroad Bridge are:

Modified Allowable Fatigue Stress Range

Stress Category	Other Than Fracture-Critical/Fracture-Critical Modified Number of Constant Stress Cycles, N			
	20,000	50,000	220,000	260,000
D	47/37	34/28	19/16	21/17

A comparison of the modified allowable fatigue stress ranges with the actual member stress ranges shown on Pages 154 and 155 and reveal that all of the actual member stress ranges for all seven loading cases are less than the modified allowables, except for 12.1% and 14.2% overstresses, respectively, in the lift and tower span intermediate floorbeams; and 2.4% and 5.7% overstresses, respectively, in the lift and lower span stringers, due to Cooper E80 loading. These overstresses are of academic interest only since the bridge was designed only for Cooper E60 loading and currently rates Cooper E80 based on strength criteria and Cooper E70 based on modified fatigue criteria.

Summary and Recommendations

The ratings of the lift and tower span members were determined for both strength and fatigue requirements in accordance with Article 7.3 - Rating, of the 1983 AREA Specifications. The ratings for the bridge, based on strength and modified fatigue requirements, respectively, are Cooper E80 and Cooper E70. These values are the ratings for the tower span intermediate floorbeams.

The Cooper E70 rating is based on modified allowable fatigue stress ranges, using past and projected traffic records, assuming a 100-year life for the Buzzards Bay Railroad Bridge.

The maximum live loading that the bridge is currently subjected to is the Bay Colony Railroad coal train, which produces stresses in the stringers equivalent to a Cooper E53 loading. The Bay Colony Railroad typical train produces stresses in the stringers equivalent to a Cooper E40 loading. The 125 ton Alco diesel-electric locomotives, operated by both the Bay Colony Railroad and the Hyannis and Cape Cod Railroad produce stresses in the floorbeams equivalent to a Cooper E40 loading.

Thus, the current freight trains pulled by Alco 125 ton locomotives produce stresses in the floor system members equivalent to Cooper Series Live Loadings between E40 and E53, which are less than the aforementioned modified fatigue based Cooper E70 rating for the bridge. Also, the equivalent Cooper E53 live load loading produced by the Bay Colony Railroad coal train represents only 0.7 percent of trains that annually traverse the bridge. Because of relative low equivalent Cooper E Series live loadings between E40 and E53, and very low traffic density, the Buzzards Bay Railroad Bridge has a projected fatigue life of 100 or more years. This life is based on the fatigue lives of the hangers, stringers and floorbeams, assuming no significant member section loss or other deficiencies.

We concur with the recommendations made in the January, 1972 Inspection and Condition Report that the lift span be lowered to "emergency position", with its lower chord approximately aligned with the tower span top chords when the intensity of a storm is such that it is necessary to close the channel to shipping.

To facilitate future fatigue studies, it is recommended that comprehensive traffic records be maintained. The traffic data should include number of trains, types of trains, and number of locomotives and cars per train.

PART V-8

SUMMARY OF RECOMMENDATIONS AND COSTS

PART V-8 - SUMMARY OF RECOMMENDATIONS AND COSTS

A summary of the recommended repairs and their estimated costs is presented in this Part. In accordance with the agreement, this information is presented in tabular form. Priority ratings are shown for each repair, and the estimated costs are separated into labor and materials. Where a repair recommendation involves work which is not extensive enough to require the services of an outside contractor, it is noted for performance by the normal maintenance personnel assigned to the bridge and no labor cost has been estimated.

The total cost of labor and materials to execute all of the recommendations is estimated to be approximately $3,877,000 above normal maintenance costs. The major portion of these costs result from the recommendations for a major overhaul and replacement of the main counterweight ropes, the counterweight trunnion bearings, and providing for permanent cable vibration eliminating devices.

The second most costly item is the recommended replacement of the electrical control system. Another high cost item is the cleaning and repainting of the steel superstructure.

Of all the foregoing major repair items, it is essential that the mechanical equipment, including the counterweight ropes, the counterweight trunnion bearings and the cable vibration limiting devices be recognized as critical to the continued safe operation of the lift span. Aside from several relatively low cost priority items related to life safety, the recommendation for the replacement of the electrical control system should next be addressed and undertaken as a priority item. Also, the remaining recommended repairs to the machinery should be scheduled to be performed concurrently with the replacement of the electrical control system.

The estimated costs are based on current prices, and do not include any allowance for administration or engineering inspection of the repair work.

Buzzards Bay Railroad Lift Bridge over Cape Cod Canal

Summary of Recommendations and Costs

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs		
				Labor	Materials	Total
SUBSTRUCTURE	Backstay Anchorages					
	1. Replace two bolts and tighten a third fastener in the northeast anchorage metalwork. Replace a similar fastener at the southeast anchorage.	14	2	$ 70	$ 30	$ 100
	2. Trim vegetation at all units and remove debris from pit at northeast anchorage.	14	3	150	40	190
	3. Thoroughly sandblast clean and paint metalwork.	14	2	100	40	140
	Abutments					
	4. Replace the displaced and cracked mortar fill around the center bearing base plate on Abutment A.	15	2	200	60	260
	5. Clean granite facing joints of loose mortar and replace about 6 and 4 linear feet of missing pointing at Abutments A and D, respectively.	15	2	180	50	230
	6. Replace the two steel support brackets attached to the coping of Abutment D.	15	2	200	60	260
	Piers					
	7. Repair spalled and unsound concrete areas on the horizontal and vertical surfaces of the pier copings.	15	2	750	250	1,000

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs: Labor	Estimated Costs: Materials	Estimated Costs: Total
SUBSTRUCTURE (Continued)	Piers (Continued)					
	8. Clean granite facing joints of loose mortar and replace about 62 and 50 linear feet of missing pointing at Piers B and C, respectively.	15	2	900	450	1,350
	9. Burn off the three sections of sheet piling at the channel bottom at the southeast corner of Pier B.	15	3	2,500	800	3,300
	10. Replace the lock bars and eye-bolt anchors for the corrugated covers over the submarine ducts in both piers.	15	3	450	200	650
	Surveys					
	11. Establish new horizontal control Monuments AE and AW on the south side of the channel.	15	3	575	225	800
	12. Continue periodic alignment, elevation and sounding checks for the bridge substructure.	15	-	-	-	-
		SUBSTRUCTURE TOTAL		$ 6,075	$ 2,205	$ 8,280

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs		
				Labor	Materials	Total
SUPERSTRUCTURE	General					
Lift Span	1. Cleaning and painting of the span is recommended within the next five years. A thorough sandblast cleaning should be specified at areas of corrosion, lamination and packed rust on members and joints.	30	2	$ 93,000	$ 76,000	$169,000
	2. Replace the truss and sway frame lacing bars listed on Table 2-1.	30	2	7,850	7,870	15,720
	Bearings					
	3. Remove the graphite compound from the non-contact surfaces of the bearings, centering devices and span lock assemblies. Remove all corrosion from the steel surfaces and apply paint to the surfaces not in bearing and lubricant at the contact surfaces.	30	2	490	220	710
	4. Replace a total of 40 fasteners connecting the upper shoes of the fixed and expansion bearings to the trusses. Replace a total of 64 fasteners in the upper shoes of the truss centering castings.	30	2	5,890	3,090	8,980
	5. Provide an outlet for trapped moisture in the lower shoes of the fixed castings.	30	2	980	350	1,330

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
SUPERSTRUCTURE	Trusses					
Lift Span (Continued)	6. Trim the interior edge of the upper flange angle and cover plate at Panel Point U0, east and west trusses, and Panel Point U0', west truss.	31	1	1,470	530	2,000
	7. Replace a missing bolt in the upper stay plate on the north side of the vertical at Panel Point U4, east truss, and two bolts in the upper stay plate on the south side of the vertical at Panel Point U4', west truss.	31	2	245	95	340
	Top Lateral and Sway Frame Bracing					
	8. Replace a missing bolt in the lateral bracing connection at Panel Point U5', west truss. The fastener is missing on the north side of the strut.	31	2	80	30	110
	9. Replace the following sway frame bracing angles: a) Panel Point 2 - The upper north angle on Member KF and the lower north angle on Member GC. b) Panel Point 8' - The lower north angle on Member KG. c) Panel Point 2' - The upper north angle on Member KF.	31	2	1,230	860	2090

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Estimated Costs Materials	Estimated Costs Total
SUPERSTRUCTURE	Top Lateral and Sway Frame Bracing (Continued)					
Lift Span (Continued)	10. Remove the counterweight rope take-up bars from the bottom flange of the lifting girders during replacement of the ropes, and thoroughly sandblast clean and paint the lifting girder webs and lower flanges and the take-up bars.	31	2	1,960	1,210	3,170
	11. Replace two deteriorated fasteners nuts for the east counterweight rope guide casting on the south side of the lifting girder at Panel Point U0.	31	2	80	30	110
	12. Provide drain holes in the upturned angle on the tower side of the end portal strut at Panel Points U0 and U0'.	31	2	250	90	340
	Floor System and Lower Lateral Bracing (Locations of Members and Joints are shown on Figure 2-4)					
	13. Replace deteriorated rivets in the bottom flanges of the following floorbeams:					
	a) Panel Point 7 - One rivet in the north flange on the outboard side of the west stringer.					

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
SUPERSTRUCTURE Lift Span (Continued)	Floor System and Lower Lateral Bracing (Locations of Members and Joints are shown on Figure 2-4) (Continued)					
	b) Panel Point 7' - Two rivets in the north flange, one below the west stringer and one on the outboard side of the east stringer.					
	c) Panel Point 3' - Four rivets in the north flange, one below each stringer and two between the stringers. One rivet in the south flange below the west stringer.					
	d) Panel Point 2' - One rivet in the south flange between the stringers.	31 & 32	2	490	190	680
	14. In Panel 3'-4', replace one rivet each in the northeast and southwest stringer-lateral bracing connections.	32	2	80	30	110
	Walkways, Platforms and Ladders (Locations of Members and Joints are shown on Figure 2-4)					
	15. Replace one missing rivet in the west stringer connection of walkway support channel member 29.	32	2	80	30	110

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
SUPERSTRUCTURE Lift Span (Continued)	Walkways, Platforms and Ladders (Locations of Members and Joints are shown on Figure 2-4) (Continued)					
	16. Replace the end cap for the lower railing pipe at the bottom of the north stairs. Replace the short section of pipe for the tee connection and provide new fasteners for the elbow sections of the railings at the top of the south stairs.	32	1	250	110	360
	17. Provide new fasteners with lock washers for the upper angle railing sections between Panel Points 2 and 3.	32	1	250	110	360
	18. Replace the 2 x 4 inch guard timber between the walkway grating and the end of the ties.	32	1	1,720	820	2,540
		LIFT SPAN TOTAL		$116,395	$ 91,665	$208,060

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs		
				Labor	Materials	Total
SUPERSTRUCTURE	General					
North Approach Span and Tower	1. Cleaning and painting should be accomplished on the truss and the tower span members within the next five years. A thorough sandblast cleaning is necessary at "pockets" of corrosion and lamination, prior to repainting.	45	2	$ 43,000	$ 35,000	$ 78,000
	2. Replace the lacing bars listed on Table 2-2 in conjunction with cleaning and painting of the structure.	45	2	6,570	6,580	13,150
	Trusses					
	3. Replace the deteriorated electrical cable support angles on the east truss members at Panel Points 2 and 4 and in the east end of the top chord strut at Panel Point 1.	45	1	370	180	550
	4. Replace ten rivets in the lower lateral connection plate at Panel Point L4, east truss.	45	2	500	200	700
	Top Lateral and Sway Frame Bracing					
	5. Replace twelve rivets in the east stay plate of the upper portal strut at Panel Point 4. Replace the batten plate at Point E on the upper strut.	45	2	650	250	900

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
SUPERSTRUCTURE	Floor System and Lower Lateral Bracing					
North Approach Span and Tower (Continued)	6. Replace five rivets in the top flange of the floorbeam at Panel Point 1 and the top flange of the floorbeam at Panel Point 3 below the walkway grating.	45	2	500	200	700
	7. Replace the missing nut on a fastener in the stringer bracing connection at Joint 7 between Panel Points 3 and 4.	45	2	75	25	100
	8. Replace four bolts with deteriorated nuts for the rail locking mechanism at Panel Point 0.	45	2	90	40	130
	Jacking Strut					
	9. Provide new shim plates for the jacking strut. Store the plates in the north tower machinery room.	46	2	70	30	100
	Tower Members					
	10. Sandblast clean and repaint the horizontal diaphragm plates and angles inside the front columns. Replace rivets in the diaphragm plate connections of the west column as follows:					
	a) First perforation above Joint D, replace 31 rivets.					
	b) Second perforation above Joint D, replace 14 rivets.					

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
SUPERSTRUCTURE	Tower Members (Continued)					
North Approach Span and Tower (Continued)	c) First perforation below Joint J, replace 6 rivets.					
	d) Second and third perforations above Joint J, replace 6 rivets in each.					
	e) Provide a bird screen at the second perforation above Joint N.	46	2	2,000	990	2,990
	11. Remove electrical conduit support angles on the interior web plates of the rear tower columns. Sandblast clean and paint web plate metalwork and re-attach angles. Eliminate angles not presently utilized.	46	2	1,800	700	2,500
	12. Reinforce the lower south angle of the transverse strut at Joint C1.	46	2	350	100	450
	13. Thoroughly clean upper surface and rivet heads of the lower transverse strut metalwork at Joint C0 and provide drain holes in web plate. Repaint cleaned areas.	46	2	600	500	1,100
	14. Replace 13 deteriorated rivets fastening the counterweight guide angles to the tower metalwork.	46	2	650	250	900

Summary of Recommendations and Costs (Continued)

Location		Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Estimated Costs Materials	Estimated Costs Total
SUPERSTRUCTURE	Top of Tower						
North Approach Span and Tower (Continued)	15.	Thoroughly clean and paint sheave girder lower flanges, connection plates and webs adjacent to the sheaves and the upper flanges at the east and west entrances to the sheave room.	46	2	730	300	1,030
	16.	Remove the pin collars between counterweight hanger plates. Thoroughly sandblast clean the metalwork, repaint and reinstall the pin collars with new bolts.	46	2	730	300	1,030
	17.	Replace the 18" x 3/8" horizontal plate attached to the outboard lower flange of sheave girders G1-E and G1-W.	46	2	490	210	700
	18.	Replace the lower ends of the outboard stiffening angles for sheave girders G1-E and G1-W.	46	2	500	230	730
	19.	Replace the gratings and connection fasteners on the sheave girder bottom flanges adjacent to the counterweight ropes.	47	1	980	1,010	1,990
	20.	Analyze the loads on the catenary brackets atop the towers to determine if corrective measures are required.	47	1	2,000	-	2,000
	21.	Replace four fasteners at the southwest corner and six fasteners at the southeast corner of the sheave girder enclosure.	47	2	500	200	700

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Estimated Costs Materials	Estimated Costs Total
SUPERSTRUCTURE	Top of Tower (Continued)					
North Approach Span and Tower (Continued)	22. Remove corrosion deposits and refasten the separated bracing members in the spire lattice at locations indicated on Figure 2-7. Bracing members with excessive section loss should be replaced.	47	1	2,000	800	2,800
	23. Replace 18 rivets in the roof splice plate below each support for the four decorative balls.	47	2	2,200	800	3,000
	24. Replace broken machinery house window panes and the metal frame around the single pane in the west entrance door to the sheave room.	47	3	200	150	350
	Walkways, Platforms and Ladders					
	25. Install a new section of railing post at the east end of support channel 17. Provide new lengths of horizontal pipe railing sections; one above channel 17 and two above channel 19. Replace two fasteners in the connection of the outboard railing post to the stairway stringer at support channel 26.	47	2	500	440	940
	26. Replace the short ladder used for access to the main counterweight.	47	1	400	250	650
	27. Replace two fasteners at the lower end of the access ladder on the south side of the sheave room at bridge centerline.	47		80	50	130

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
SUPERSTRUCTURE	Walkways, Platforms and Ladders (Continued)					
North Approach Span and Tower (Continued)	28. Replace two fasteners in the outboard connection of the vertical access ladder and two adjacent fasteners in the vertical support angle for the catenary platform at the southeast corner of the machinery house.	47	2	90	60	150
	29. Replace the east and west vertical straps for the ladder cage on the north side of the machinery house.	47	2	450	200	650
	30. Replace the 2" x 4" guard timber between the walkway grating and the ties.	47	1	400	190	590
	Control House					
	31. Repair the lower end of the south entrance door to the transformer room.	47	3	300	200	500
	NORTH APPROACH SPAN AND TOWER TOTAL			$ 71,775	$ 50,435	$122,210

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
SUPERSTRUCTURE	General					
South Approach Span and Tower	1. Cleaning and painting is recommended for the span and tower members, machinery house and spire within the next five years. A thorough sandblast cleaning should be specified at areas of corrosion, lamination and packed rust on members and joints.	54	2	$ 43,000	$ 35,000	$ 78,000
	2. Replace the lacing bars in truss and tower members listed in Table 2-2.	54	2	4,700	4,700	9,400
	Trusses					
	No specific repairs are recommended.	54	-	-	-	-
	Top Lateral and Sway Frame Bracing					
	3. Install five fasteners in the bracing west top chord connection at Panel Point 4. Install three bolts in the bracket supporting the ornamental ironwork on the portal strut at Panel Point 4.	54	2	470	170	640
	Floor System and Lower Lateral Bracing					
	4. Replace one fastener in the lateral bracing splice plate in Panels 2-3 and 3-4.	54	2	75	25	100
	5. In Panel 3-4, replace one rivet at the east connection of the first lower angle strut south of L3 between stringers.	54	2	75	25	100

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs: Labor	Materials	Total
SUPERSTRUCTURE	**Jacking Strut**					
South Approach Span and Tower (Continued)	6. Provide replacement shim plates for the north end of the jacking strut. Store the plates in the north tower machinery room.	55	2	70	30	100
	Tower Members					
	7. Remove the bird screens and thoroughly clean and paint the horizontal diaphragms and connection metalwork in the tower front columns. Replace screens after cleaning and painting.	55	2	2,000	1,000	3,000
	8. Remove the electrical conduit support angles attached to the interior web plates of the tower rear columns to thoroughly clean and repaint. Do not re-attach angles not presently being utilized.	55	2	1,800	700	2,500
	9. Replace the four lacing bars and adjacent stay plate at the east end of the strut at Point [illegible]. Replace eight rivets in the adjacent transverse sheave girder bottom flange.	55	2	980	220	1,200
	10. Ream the existing hole and install a bolt at the upper end of the tower member AO(west)-H.	55	2	80	50	130
	11. Trim the deteriorated lower flange at the upper end of the tower east bracing member P-C1. Trim the deteriorated area of the adjacent stay plate.	55	2	400	150	550

Summary of Recommendations and Costs (Continued)

Location		Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
SUPERSTRUCTURE	Tower Members (Continued)						
South Approach Span and Tower (Continued)	12.	Replace two rivets in the lower connection of tower member AO(east)-M. The connectors fasten the member to the south vertical gusset plate at the joint.	55	2	80	30	110
	13.	Replace ten rivets in the lower flange of the outboard channel and four rivets in both the upper and lower inboard channel flanges of the east tower member CO-C1 lacing connections.	55	2	580	220	800
	14.	Replace eight rivets in the upper flange and two rivets in the lower flange of the inboard channel and three rivets in the upper flange of the outboard channel of the west tower member CO-C1 lacing connections.	55	2	600	200	800
	15.	Replace 10 rivets fastening the east counterweight guide angles to the tower metalwork.	55	2	500	200	700
	Top of Tower						
	16.	Thoroughly clean and paint areas of debris accumulation and corrosion of sheave girder webs, flanges, connection plates and small access gratings.	55	2	800	350	1,150

Summary of Recommendations and Costs (Continued)

Location		Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
SUPERSTRUCTURE		Top of Tower (Continued)					
South Approach Span and Tower (Continued)	17.	Remove the pin collars and thoroughly clean and repaint the interior surfaces of the counter-weight hanger connection metalwork. Clean pin collars and provide new connection bolts.	55	2	730	300	1,030
	18.	Replace the 18" x 3/8" horizontal plates adjacent to the outboard lower flanges of sheave girders G1-E and G1-W.	56	2	490	210	700
	19.	Replace the lower ends of the outboard stiffening angle for sheave girders G1E and G1-W.	56	2	500	230	730
	20.	Analyze the catenary bracket supports atop the towers to determine if corrective measures are required.	56	1	2,000	-	2,000
	21.	Remove corrosion deposits and refasten the broken connections of the spire lattice angles at locations listed in Figure 2-7. Replace severely deteriorated angles as necessary.	56	1	2,000	800	2,800
	22.	Replace 18 rivets in the machinery house roof splice plates beneath each support for the decorative balls.	56	2	2,200	800	3,000

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
SUPERSTRUCTURE	Top of Tower (Continued)					
South Approach Span and Tower (Continued)	23. Replace broken window panes and deteriorated window frames of the machinery room and single frame in the south door of the west entrance to the sheave room.	56	3	200	180	380
	24. Repair deteriorated cornice on east side of machinery house.	56	3	1,000	600	1,600
	Walkways, Platforms and Ladders					
	25. Replace two rivets in the west stringer top flange connection of the walkway support channel 17. A vertical support for the jacking strut is attached to this member on the west end.	56	2	80	50	130
	26. Replace a deteriorated fastener at the southeast corner of the access platform on east member M'-M and a fastener at the north end of the outboard channel for the member M'-M.	56	2	80	50	130
	27. Replace the short vertical access ladder atop the tower leading to the main counterweight.	56	1	400	250	650
	28. Replace the hoops and vertical straps on the ladder leading to the spire at the south side of the machinery house. Replace the top rung of the ladder.	56	1	450	220	670
	29. Refasten the loose connection at the base of the short access ladder in the decorative ball atop the spire.	56	1	80	50	130

Summary of Recommendations and Costs (Continued)

Location		Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
SUPERSTRUCTURE		Walkways, Platforms and Ladders (Continued)					
South Approach Span and Tower (Continued)	30.	Replace the 2 x 4 inch guard timber between the walkway grating and timber ties.	56	1	400	190	590
		SOUTH APPROACH SPAN AND TOWER TOTAL			$ 66,820	$ 47,000	$113,820

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
ELECTRICAL EQUIPMENT	Incoming Commercial Power					
	1. Replace the high voltage fuse assemblies on the control house roof.	90	2	$ 125	$ 100	$ 225
	2. Contact resistance should be lowered on both General Electric 5 KV load break disconnect switches in the transformer room by tightening the moving main contact gap.	90	3	500	-	500
	3. Replace the high voltage primary wiring to the 15 KVA transformer bank.	90	2	125	75	200
	4. The three 15 KVA transformers should each be taken out of service, covers removed, and oil level visually checked.	90	2	500	-	500
	5. As a preferred alternative to 4. above, replace the three aged 15 KVA oil-filled transformers with new dry-type transformers, thus eliminating future oil maintenance and the potential fire hazard associated with oil transformers.	91	2	1,000	2,000	3,000
	6. The three 150 KVA transformers should each be taken out of service and their oil changed.	91	2	1,000	1,000	2,000

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
ELECTRICAL EQUIPMENT (Continued)	Incoming Commercial Power (Continued)					
	7. As a preferred alternative to 6. above, replace the three aged 150 KVA oil-filled transformers with new dry-type transformers, thereby eliminating the future oil maintenance and potential fire hazard associated with oil transformers.	91	2	5,000	15,000	20,000
	Emergency Engine-Generator					
	1. Lubricate main generator bearings via the oil cup fill tubes located under the access covers at both ends.	91	1	RR	50	50
	2. Repair intake and exhaust louver operating motor circuit.	91	2	250	100	350
	3. Install strip heater in generator control/switchgear cabinet to combat condensation and dampness.	91	3	125	50	175
	4. Repair the diesel engine overspeed safety shutdown.	91	1	1,500	250	1,750
	5. Repair or replace the emergency start and stop valves which are presently inoperative due to excess paint.	91	2	500	500	1,000
	6. Replace the missing handle for the engine lube oil strainer and incorporate its use into the engine operation procedure.	91	1	RR	25	25

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
ELECTRICAL EQUIPMENT (Continued)	**Emergency Engine-Generator** (Continued)					
	7. Repair or replace the water jacket thermostat.	91	2	250	25	275
	Main Switchboard					
	1. Burnish pitted contacts on contactors, and replace cracked or broken arc chutes (if replacement parts can be obtained).	91	3	-	-	-
	2. Periodically re-inspect auxiliary contact linkages on contactors and rebuild when necessary.	91	3	RR	-	-
	3. Replace the various power circuit wiring and/or motors as necessary to correct the low megger readings for the south rail lock and lower span lock motor.	91	3	2,500	5,000	7,500
	4. Isolate and correct the low megger readings (below 0.5 megohms) obtained from the skew limit switches, lock control, main span limit switch, railroad signal interlocking, and normal span control interlocking. (See readings noted in the tabulation in Appendix A).	91	3	5,000	10,000	15,000
	5. Replace faulty and inappropriately sized fuses (see tabulation in Appendix A).	91	2	RR	25	25
	6. Replace missing mounting bolt in resistor mount.	92	2	50	10	60

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs		
				Labor	Materials	Total
ELECTRICAL EQUIPMENT (Continued)	Emergency Engine-Generator (Continued)					
	7. The bridge control system, in general, is antiquated. This control system, including the main switchboard, should be replaced with a modern, enclosed, automatic (single push button) system. This would not only eliminate the replacement parts procurement problem, but also the shock hazards presented by the existing open front, exposed contact type of equipment.	92	2	350,000	250,000	600,000
	Control Desk					
	1. Repair power selsyn transfer wattmeter.	92	2	125	250	375
	2. Recalibrate the ammeters.	92	2	125	250	375
	3. Replace control deck (or at lest the control panel and metering) at such time as the control system is replaced, as recommended in 5. above under "Main Switchboard".	92	2	-	-	-
	Limit Switches					
	1. Clean and dry the span seating limit switches. Drill a 3/16 inch drain hole in bottom corner of each switch.	92	2	RR -	-	-

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
ELECTRICAL EQUIPMENT (Continued)	Limit Switches (Continued)					
	2. Periodically inspect the main span limit switches (rotary cam type) in the north machinery house, and the skew limit switches in both machinery houses. Dress the contacts as necessary.	92	3	RR	-	-
	3. Clean and dry the rail lock limit switches. Drill a 3/16 inch drain hole in bottom corner of each switch.	92	3	RR	-	-
	4. Replace all brake hand release limit switches.	92	2	1,000	1,200	2,200
	5. Provide brakes released limit switches on all thruster brakes at such time as control system is replaced; it may not be feasible with existing equipment. Correct control interlocking should prohibit span drive motor operation until brakes are released, except for the drag brake function.	92	2	2,500	1,500	4,000
	Navigation Lights and Aerial Beacons					
	1. Clean all paint spray off of navigation light lenses.	92	2	RR	-	-
	2. Replace sun shields and mirrors on the flashing span mounted navigation lights.	92	3	1,000	200	1,200

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
ELECTRICAL EQUIPMENT (Continued)	Navigation Lights and Aerial Beacons (Continued)					
	3. Replace aerial beacon lamps with the correct type approved by the FAA for aerial obstruction marking (620 or 700 watt incandescent).	92	2	500	150	650
	Catenary Cables					
	1. At the northeast catenary bracket, the center secondary cable (of five cables), which is contacting the inboard backstay cable, should be disconnected from the bracket and placed on the opposite side of the backstay. Wrap the power/control with a protective shield if necessary for abrasion or rubbing protection after the above relocation.	93	2	2,000	300	2,300
	2. The catenary cable system should be inspected every two or three years to monitor the minor corrosion noted on the support angles, the grade clamps, and the wire ropes.	93	3	-	-	-
	Tower and Lift Span Conduits					
	1. Replace rusted conduits on the north tower bottom and on the north tower span.	93	2	35,000	2,500	37,500

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Estimated Costs Materials	Estimated Costs Total
ELECTRICAL EQUIPMENT (Continued)	Tower and Lift Span Conduits (Continued)					
	2. Repair the plastic conduit carrying the ground wire and the conduit supports at the north abutment. Eliminate surplus ground wire and all unnecessary bends and kinks. 3. Repair broken conduit body, provide proper conduit supports, and terminate conduit with an insulating bushing oriented downward at north abutment. 4. Replace broken plastic conduit with galvanized steel conduit and provide proper conduit supports on the south tower span. 5. Replace missing conduit body cover and miscellaneous rusted conduit support clamps. 6. Replace rusted conduits and supports along the lift span walkway and stairways.	93	2	2,000	150	2,150
	7. Remove miscellaneous abandoned loose wires at tower bottoms.	93	3	1,000	-	1,000
		ELECTRICAL TOTAL		$413,675	$290,710	$704,385

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs		
				Labor	Materials	Total
COUNTERWEIGHTS	General					
	1. Repair the spalled and unsound concrete areas in the cap of the south main counterweight (approximately 59 square feet) and clean and seal the concrete surfaces at both main counterweights.	95	2	$ 3,000	$ 1,800	$ 4,800
	2. Clean and paint the undersides of the well covers of both main counterweights.	95	2	600	350	950
	3. Replace deteriorated well cover fastener nuts for the south main counterweight at four anchor bolts.	95	2	120	80	200
	4. Replace the deteriorated caulking around the hanger metalwork at each main counterweight.	95	2	400	180	580
	5. Thoroughly clean and paint the hanger metalwork of both the main and auxiliary counterweights.	95	2	1,500	900	2,400
		COUNTERWEIGHTS TOTAL		$ 5,620	$ 3,310	$ 8,930

Summary of Recommendations and Costs (Continued)

Location		Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
MECHANICAL EQUIPMENT	1.	Institute a program to replace all corroded bolts and/or nuts. This includes: a. Assembly bolts on machinery such as: 1. Connecting rods on lock bars 2. Speed reducers 3. Buffer cylinders 4. Bearing caps 5. Span guides b. Mounting bolts for all machinery components. c. Foundation bolts for the lower span machinery.	125 & 126	1	$ 7,500	$ 7,500	$ 15,000
	2.	Clean, polish and protect the bearing journals on the idler gear shafts for the 50 HP emergency span drives. Include all components of the emergency drive in preventive maintenance program.	126	3	RR	-	-
	3.	Reactivate limit switches on all span drive brakes, making sure that they are properly interlocked in the control circuit.	126	2	RR	-	-

Summary of Recommendations and Costs (Continued)

Location		Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs		
					Labor	Materials	Total
MECHANICAL EQUIPMENT (Continued)	4.	Replace check valves and pressure regulating valves on all buffers. Connect pairs of buffers at each end of span and in each tower with piping and one pressure regulating valve to equalize pressure in each pair of buffers. Adjust pressure regulating valve to build up sufficient pressure during seating of the span to eliminate the necessity of setting the machinery brakes during seating. After replacing valves and repiping the buffers, if the proper pressure cannot be obtained in any cylinder, that cylinder should be disassembled and rehabilitated as necessary.	126	2	36,000	40,400	76,400
	5.	Replace Gearset PG_1-SG_1 in both lower span lock drives.	126	3	6,700	22,500	29,200
	6.	Determine why the clutches in the span drive differential have been deactivated. Unless some compelling reason is found why they must be deactivated, they should be reactivated.	126	2	RR	-	-
	7.	Interim procedure:					
		a. Clean and relubricate all existing main and auxiliary counterweight ropes. Use a lubricant that will penetrate the core of each rope and displace water.	126	1	78,700	1,700	80,400

Summary of Recommendations and Costs (Continued)

Location	Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
MECHANICAL EQUIPMENT (Continued)	b. Provide vibration limiting devices on counterweight ends of all counterweight ropes.	126	1	2,400	1,600	4,000
	c. Remove all debris from area of counterweight rope socket at attachments to the counterweights.	126	1	RR	-	-
	8. Replace guides at rope attachments at counterweights. 9. Provide permanent vibration limiting devices at counterweight ends of ropes to reduce abrasion between ropes and grooves in guides. 10. Replace all main and auxiliary counterweight ropes as soon as practical.	126	1	806,000	349,000	1,155,000
	11. Replace counterweight trunnion bearings assemblies. Use bearings that are dimensionally interchangeable with existing bearings so that existing bearing housings can be reused. Replacement bearings should be spherical roller or tapered roller types that provide both radial and thrust capacity. One bearing on each trunnion shaft should be fixed and the second bearing should float to allow for differential thermal expansion.	127	1	806,000	484,000	1,290,000

Summary of Recommendations and Costs (Continued)

Location		Repairs Recommended	Report Page Reference	Repair Priority	Estimated Costs Labor	Materials	Total
MECHANICAL EQUIPMENT (Continued)	12.	Replace the entire plumbing system in the control house, per the recommendations included in George Jackson's report in Appendix B.	127	3	18,500	26,500	45,000
	13.	Redesign counterweight guide slippers to provide bronze slipper inserts in each slipper.	127	3	9,600	6,000	15,600
			MECHANICAL TOTAL		$1,771,400	$939,200	$2,710,600

Priority Ratings:

1. High priority repair to ensure safety and integrity of structure.

2. Repairs to correct deterioration that currently does not jeopardize the safety and integrity of the structure. Repairs to reduce probability of future deterioration and maintenance.

3. Repairs to minor items, improvements in appearance of structure and routine maintenance procedures.

RR Indicates repair work which is not extensive enough to require the services of an outside contractor, but which could be performed by the normal maintenance personnel assigned to the bridge.

Buzzards Bay Railroad Lift Bridge over Cape Cod Canal

Summary of Estimated Costs

	Total	Priority 1	Priority 2	Priority 3
Substructure	$ 8,280	--	$ 3,340	$ 4,940
Superstructure				
Lift Span	208,060	$ 5,260	202,800	--
North Approach Span and Tower	122,210	8,580	112,780	850
South Approach Span and Tower	113,820	6,840	105,000	1,980
Electrical Equipment	704,385	1,825	677,185	25,375
Counterweights	8,930	--	8,930	--
Mechanical Equipment	2,710,600	2,529,400	76,400	89,800
TOTAL	$3,876,285	$2,566,905	$1,186,435	$ 122,945

APPENDIX A

ELECTRICAL EQUIPMENT TESTS

TEST NO. 1: NORMAL POWER AND SYNCHRO-TIE SYSTEM

Motor Combinations - Traction Motors: "A" North Tower
"C" South Tower
Synchro-Tie Motors: "B" North Tower
"D" South Tower

Span Height (Feet)	Lower North (Amps)	Lower South (Amps)	Lower Transfer (KW)	Raise North (Amps)	Raise South (Amps)	Raise Transfer (KW)
0	110	110	20	150	150	10
10	0	0	0	120	120	8
20	95	95	10	115	115	8
30	95	95	10	115	115	10
40	95	95	8	110	110	10
50	100	100	10	105	105	8
60	100	100	8	105	105	8
70	100	100	8	100	100	8
80	100	100	10	105	105	10
90	100	100	8	105	105	10
100	100	100	10	105	105	10
110	100	100	10	110	105	10
120	100	100	8	110	110	10
130	110	110	10	115	110	10

TEST NO. 2: NORMAL POWER AND SYNCHRO-TIE SYSTEM

Motor Combinations - Traction Motors: "B" North Tower
"D" South Tower
Synchro-Tie Motors: "A" North Tower
"C" South Tower

Span Height (Feet)	Lower North (Amps)	Lower South (Amps)	Lower Transfer (KW)	Raise North (Amps)	Raise South (Amps)	Raise Transfer (KW)
0	115	110	20	150	150	10
10	110	105	10	140	135	10
20	105	100	10	125	120	10
30	105	100	10	120	115	10
40	105	100	8	115	110	10
50	105	100	8	115	110	10
60	105	100	10	110	105	10
70	100	105	10	110	105	10
80	115	110	10	110	105	10
90	105	100	5	110	105	10
100	105	95	8	110	105	10
110	105	95	10	110	105	10
120	105	100	10	115	110	10
130	110	100	5	115	110	10

TEST NO. 3: EMERGENCY POWER AND SYNCHRO-TIE SYSTEM

Motor Combinations - Traction Motors: "A" North Tower
"C" South Tower
Synchro-Tie Motors: "B" North Tower
"D" South Tower

Span Height (Feet)	Lower North (Amps)	Lower South (Amps)	Lower Transfer (KW)	Raise North (Amps)	Raise South (Amps)	Raise Transfer (KW)
0	125	125	15	170	170	10
10	120	120	10	130	125	10
20	105	105	8	135	130	10
30	105	105	10	115	115	8
40	110	110	8	115	115	5
50	110	110	8	110	110	10
60	110	110	10	112	110	10
70	110	110	10	110	110	8
80	110	110	10	110	110	8
90	110	105	10	115	110	5
100	110	110	10	115	112	8
110	110	110	10	115	112	10
120	115	115	8	120	120	10
130	120	120	5	120	120	10

TEST NO. 4: EMERGENCY POWER AND SYNCHRO-TIE SYSTEM

Motor Combinations - Traction Motors: "B" North Tower
"D" South Tower
Synchro-Tie Motors: "A" North Tower
"C" South Tower

Span Height (Feet)	Lower North (Amps)	Lower South (Amps)	Lower Transfer (KW)	Raise North (Amps)	Raise South (Amps)	Raise Transfer (KW)
0	130	120	20	160	150	15
10	120	110	15	140	130	10
20	115	105	10	130	125	8
30	115	105	10	125	120	8
40	115	105	10	125	120	8
50	115	105	8	120	115	10
60	115	105	8	115	110	10
70	115	105	10	120	110	10
80	115	105	10	120	110	10
90	115	105	10	120	115	8
100	115	105	8	120	115	8
110	115	110	8	120	115	10
120	115	110	10	125	115	10
130	125	115	10	125	115	10

TEST NO. 5: NORMAL POWER - EMERGENCY OPERATION ONE MOTOR OUT OF SERVICE

Motor Combinations - Motor "B" North Tower, Out of Service
Traction Motor: "D" South Tower
Synchro-Tie Motors: "A" North Tower
"C" South Tower

Span Height (Feet)	Lower North (Amps)	Lower South (Amps)	Lower Transfer (KW)	Raise North (Amps)	Raise South (Amps)	Raise Transfer (KW)
0	0	160	70	0	170	70
10	0	100	20	0	200	100
20	0	100	20	0	150	70
30	0	100	20	0	140	60
40	0	110	30	0	130	50
50	0	110	30	0	125	40
60	0	110	30	0	120	40
70	0	110	35	0	115	30
80	0	120	40	0	120	35
90	0	105	20	0	120	40
100	0	105	20	0	120	40
110	0	105	20	0	130	40
120	0	105	20	0	120	60
130	0	110	30	0	150	70

TEST NO. 6: NORMAL POWER - EMERGENCY OPERATION ONE MOTOR OUT OF SERVICE

Motor Combinations - Motor "D" South Tower, Out of Service
Traction Motor: "B" North Tower
Synchro-Tie Motors: "A" North Tower
"C" South Tower

Span Height (Feet)	Lower North (Amps)	Lower South (Amps)	Lower Transfer (KW)	Raise North (Amps)	Raise South (Amps)	Raise Transfer (KW)
0	150	0	60	180	0	70
10	160	0	60	180	0	80
20	105	0	10	150	0	50
30	105	0	20	140	0	40
40	115	0	25	140	0	30
50	115	0	30	120	0	20
60	115	0	30	120	0	20
70	115	0	30	120	0	20
80	115	0	30	125	0	25
90	120	0	30	125	0	25
100	120	0	40	125	0	25
110	110	0	20	130	0	30
120	110	0	20	160	0	50
130	120	0	30	160	0	60

TEST NO. 7: NORMAL POWER - EMERGENCY OPERATION ONE MOTOR OUT OF SERVICE

Motor Combinations - Motor "A" North Tower, Out of Service
Traction Motor: "C" South Tower
Synchro-Tie Motors: "B" North Tower
"D" South Tower

	Lower			Raise		
Span Height (Feet)	North (Amps)	South (Amps)	Transfer (KW)	North (Amps)	South (Amps)	Transfer (KW)
0	0	170	70	0	170	70
10	0	0	0	0	130	50
20	0	100	20	0	140	50
30	0	105	25	0	150	50
40	0	110	30	0	130	50
50	0	110	30	0	125	40
60	0	110	30	0	110	20
70	0	120	40	0	115	10
80	0	105	25	0	120	10
90	0	105	25	0	120	10
100	0	105	25	0	120	10
110	0	105	25	0	110	5
120	0	105	25	0	140	40
130	0	110	30	0	140	40

TEST NO. 8: NORMAL POWER - EMERGENCY OPERATION ONE MOTOR OUT OF SERVICE

Motor Combinations - Motor "C" South Tower, Out of Service
Traction Motor: "A" North Tower
Synchro-Tie Motors: "B" North Tower
"D" South Tower

	Lower			Raise		
Span Height (Feet)	North (Amps)	South (Amps)	Transfer (KW)	North (Amps)	South (Amps)	Transfer (KW)
0	180	0	80	170	0	80
10	150	0	60	170	0	70
20	100	0	10	150	0	60
30	100	0	5	140	0	50
40	110	0	20	130	0	40
50	110	0	30	125	0	40
60	110	0	30	120	0	30
70	120	0	30	120	0	30
80	120	0	40	110	0	20
90	105	0	15	110	0	10
100	105	0	20	130	0	40
110	105	0	20	115	0	30
120	105	0	10	140	0	40
130	110	0	40	150	0	50

MEGGERING TESTS

RELAY AND CONTACTOR COILS - MAIN SWITCHBOARD
ROOM TEMPERATURE: 73 Degrees F.

Coil	Control Function	Megger Reading (MEGOHMS)
N18	North Span Normal Traction Motor-Lower	1,000
N19	North Span Normal Traction Motor-Raise	1,000
N20	South Span Normal Traction Motor-Lower	1,000
N21	South Span Normal Traction Motor-Raise	1,000
N22	Synchro Motor Excitation-Raise	1,000
N23	Synchro Motor Excitation-Lower	1,000
N24	Synchro Motor Excitation-3rd Phase	1,000
N25	Synchro Motor Excitation-3rd Phase Tieline	1,000
N41	North Normal Traction Motor Secondary	1,000
N42	North Normal Traction Motor Secondary	1,000
N43	North Normal Traction Motor Secondary	1,000
N44	North Normal Traction Motor Secondary	1,000
N45	North Normal Traction Motor Secondary	1,000
N46	South Normal Traction Motor Secondary	1,000
N47	South Normal Traction Motor Secondary	1,000
N48	South Normal Traction Motor Secondary	1,000
N49	South Normal Traction Motor Secondary	1,000
N50	South Normal Traction Motor Secondary	1,000
N55	North Brake A (Traction Motor)	1,000
N56	North Brake B	1,000
N57	South Brake D	1,000
N58	South Brake G (Traction Motor)	1,000
N59	North Brake GH (Drag Brake)	1,000
N60	South Brake JK (Drag Brake)	1,000
N61	North Rail Lock-Close	1,000
N62	North Rail Lock-Open	1,000
N63	South Rail Lock-Close	1,000
N64	South Rail Lock-Open	1,000
N65	North Lower Span Lock-Close	1,000
N66	North Lower Span Lock-Open	1,000
N67	South Lower Span Lock-Close	1,000
N68	South Lower Span Lock-Open	1,000
N69	North Upper Span Lock	1,000
N70	South Upper Span Lock	1,000
N71	North Differential Clutch	1,000
N72	South Differential Clutch	1,000
N77	Span Motor Undervoltage	1,000
N78	Span Up Limit Bypass	1,000
N79	Span Down Limit Bypass	1,000
N80	North Span Fully Open Control	1,000
N81	South Span Fully Open Control	1,000
N83	Machinery Room Heaters	1,000
N84	Skew Limit Bypass	1,000
N85	Skew Limit Bypass	1,000
N86	Contactors N22, N23 (Time Delay Relays)	1,000
N87	Contactor N24 (Time Delay Relay)	1,000
N88	Contactor N24 (Time Delay Relay)	900

Coil	Control Function	Megger Reading (MEGOHMS)
N89	Contactor N25 (Time Delay Relay)	1,000
N90	Brakes A and B (Time Delay Relays)	1,000
N91	Brakes C and D (Time Delay Relays)	1,000
N94	Brake Release Contactor	1,000
N95	North Main Span Motor Overload Alarm	1,000
N96	South Main Span Motor Overload Alarm	1,000
N97	Span Leveling (Up Master Switch On)	1,000
N98	Span Leveling (Up Master Switch On)	1,000
N99	Raise Control (Labeled Down)	1,000
N100	Lower Control	1,000
N101	Span Leveling (Selyn Indicator Raise Relay)	1,000
N102	Span Leveling (Selyn Indicator Lower Relay)	1,000
E40	Brake E (North Brake E Relay)	600
E41	Brake F (South Brake F Relay)	1,000
E42	Brake A (North Brake A Relay)	1,000
E43	Brake B (North Brake B Relay)	1,000
E44	Brake C (South Brake C Relay)	1,000
E45	Brake D (South Brake D Relay)	1,000
E46	North Brakes G and H Relay	1,000
E47	South Brakes J and K Relay	1,000
E48	North Rail Lock Close (Emergency)	1,000
E49	North Rail Lock Open (Emergency)	1,000
E50	South Rail Lock Close (Emergency)	1,000
E51	South Rail Lock Open (Emergency)	1,000
E52	North Lower Span Lock, Close (Emergency)	1,000
E53	North Lower Span Lock, Open (Emergency)	1,000
E54	South Lower Span Lock, Close (Emergency)	1,000
E55	South Lower Span Lock, Open (Emergency)	1,000
E56	North Upper Span Lock (Emergency)	1,000
E57	South Upper Span Lock (Emergency)	1,000
E58	North Differential Clutch (Emergency)	1,000
E59	South Differential Clutch (Emergency)	900
E68	Span Motor Undervoltage (Emergency)	1,000
E69	Span Up Limit Bypass (Emergency)	1,000
E70	Span Down Limit Bypass (Emergency)	1,000
E71	North Span Fully Open Control (Emergency)	1,000
E72	South Span Fully Open Control (Emergency)	1,000
E73	Skew Limit Bypass (Emergency)	1,000
E74	Skew Limit Bypass (Emergency)	1,000
E75	Brakes A, B, C, D (Time Relay)	1,000
E76	Brakes E and F (Time Relay)	1,000
E79	Setting of Service Brakes	900
E80	Span Leveling	1,000
E81	Span Leveling	1,000
E82	Raise Control	1,000
E83	Lower Control	1,000
E84	Span Leveling	1,000
E85	Span Leveling	1,000
C67	Differential Clutch Engaged Relay	1,000

MEGGERING TEST - WIRING

WIRING MEGGERED WITH END DEVICE (MOTOR, BRAKE, ETC.) CONNECTED

TEMPERATURE: INSIDE - 73 DEGREES F. - OUTSIDE - 60 DEGREES F.

Wire No.	Feeding	Megger Reading (MEGOHMS Unless Noted)
14, 15, 16	North Tower Heaters	1,000
17, 18, 19	South Machinery Room Heaters	* 600 K ohm
160, 166	Thermostat - South Tower	1,000
204, 205, 206	Motor B Stator	60
201, 202, 203	Motor A Stator	60
207, 208, 209	Motor A Rotor	70
211, 212, 213	Motor B Rotor	130
231, 232, 233	Motor C Stator	10
234, 235, 236	Motor D Stator	14
237, 238, 239	Motor C Rotor	9
241, 242, 243	Motor D Rotor	12
264, 265, 266	East Brake A	120
267, 268, 269	Brake A	1,000
277, 278, 279	North Brake B	1,000
274, 275, 276	East Brake B	140
N116, N117, N118	Brake C	1,000
E128, E129, E130	East Brake C	1,000
N113, N114, N115	Brake D	1,000
E125, E126, E127	Brake D	1,000
304, 305, 306	Brake E	1,000
E107, E108, E109	Brake F	1,000
317, 318, 319	Brakes G and H	900
N119, N120, N121	Brakes J and K	500
E131, E132, E133	Brakes J and K	1,000
331, 332, 333	Rail Lock Motor	4
N101, N102, N103	South Rail Lock Motor	* 800 K ohm
E110, E111, E112	Rail Lock Motor	1,000
341, 342, 343	Lower Span Lock Motor	* 200 K ohm
N104, N105, N106	Lower Span Lock Motor	8
E113, E114, E115	Lower Span Lock Motor	1,000
E114A, E115A	Lower Span Lock Motor	1,000
357, 358, 359	Upper Span Lock Motors	35
N107, N108, N109	Upper Span Lock Motors	* 600 K ohms
E116, E117, E118	Upper Span Lock Motors	1,000
377, 378, 379	Differential Clutch Motor	1,000
N110, N111, N112	Differential Clutch Motor	1,000
E119, E120, E121	Differential Clutch Motor	1,000
C119	Fully Closed Limit Switches	1,000
C107	Lower Span Lock Closed Limit	2
C108	Lower Span Lock Open Limit	160
C122	Lower Span Lock Closed Limit	3
C123	Lower Span Lock Open Limit	240

Wire No.	Feeding	Megger Reading (MEGOHMS Unless Noted)
453	Differential Clutch Limit Switch	1,000
C126	Differential Clutch Limit Switch	1,000
C110	Skew Limit Switch	1.8
C111	Skew Limit Switch	1,000
C112	Skew Limit Switch	1,000
C113	Skew Limit Switch	2
C115	Skew Limit Switch	300
C116	Skew Limit Switch	* 400 K ohms
C128	Skew Limit Switch	1,000
C129	Skew Limit Switch	1,000
C130	Skew Limit Switch	1,000
C131	Skew Limit Switch	1,000
C132	Skew Limit Switch	1,000
C133	Skew Limit Switch	1,000
671	Emergency Clutch Limit Switch	1,000
C134	Upper Span Locks	14
L101	Skew Transmitter Rotor	300
L102	Skew Transmitter Rotor	300
L103	Skew Transmitter Rotor	320
L104	Skew Transmitter Rotor	600
L105	Skew Transmitter Rotor	1,000
L106	Skew Transmitter Rotor	800
C101	Lock Control North and South	* 300 K ohms
C107	Lock Control North and South	1.4
C104, C127	Rail Lock Limits North and South	35
420	Lower Span Locks	2
434	Lower Span Locks	30
C103	Lower Span Locks	20
C114	Skew Limit Switch North and South	600 K ohms
520	Interlock Normal Span Control	500 K ohms
525, 538	Interlock Normal Span Control	* 100 K ohms
700	Interlock Normal Span Control	1,000
502, 546, 547	Main Span Limit Switch North	150
557, 573, 574	Main Span Limit Switch North	120
581, 584, 589	Main Span Limit Switch North	200
593, 600	Main Span Limit Switch North	200
L114	Main Span Limit Switch North	800
800	Main Span Limit Switch North	* 10 K ohms
C109	Upper Span Lock Limits	16
C124, C125	Clutch Interlocks South	1,000
538, 541	Bypass	2
L110, L111, L155	Selsyn Indicators North and South	200
L156, L157, L158	Selsyn Indicators North and South	250
805, 806, 807	Selsyn Indicators North and South	400
808, 809, 810	Selsyn Indicators North and South	300
L127, L126, L147	Indication	140
L129, L138, L149 L130, L141	Indication	300
L150, L131, L142, L151	Indication	160
L132, L143, L152, L133, L144	Indication	250

Wire No.	Feeding	Megger Reading (MEGOHMS Unless Noted)
L134, L145, L135, L146	Indication	200
L128	Indication	10
L137	Indication	16
L148	Indication	300
C117	Lock Control	90
901, 902, 903	Elevator - North Tower	2.2
904, 905, 906	Elevator - South Tower	1.6
L113, L114, L115, L116	Indication	900
L117, L119, L121, L123	Indication	20
L107	Rail Signal Interlocking North and South	* 20 K ohms
L108, L109	Rail Signal Interlocking North and South	1,000
L166	Rail Signal Interlocking North and South	10
870	Rail Signal Interlocking North and South	* 7 K ohms
888, 889, 891	Aerial Obstruction Beacon North and South	1,000
892, 893, 894	Aerial Obstruction Beacon North and South	1,000
946, 949, 932	Lighting Feeder South	1,000

*Measurements so designated are unsatisfactorily low and warrant further isolation and investigation.

PANELBOARD MEGGERING

Control Room Panelboard

Circuit 1	Inside Lights	400 K ohms
Circuit 2	Inside Lights	1,000
Circuit 3	Inside Receptacles	1,000
Circuit 4	Store Room Lights and Receptacles	1,000
Circuit 5	Span Walkway Lights	See Note 1
Circuit 6	Transfer Switch	1,000
Circuit 8	South Pier	See Note 2
Circuit 9	Generator House	See Note 2
Circuit 10	Stairway Lights	See Note 1
Circuit 11	Switchboard Lights	1,000
Circuit 12	North Pier Lights	See Note 1

South Tower Panelboard

Circuit 1	Spire Ladder Lights	See Note 1
Circuit 2	Outside Walkway Lights	1,000
Circuit 3	Motor Room Lights	1,000
Circuit 4	Motor Room Receptacles	15
Circuit 5	Elevator Lights	16
Circuit 6	Machinery Room and Catwalk Receptacles	1,000
Circuit 7	Elevator Ladder Lights	5
Circuit 8	Machinery Room Lights	900
Circuit 9	Photocell and Approach Lights	See Note 1
Circuits 11 & 13	Sodium Lights South Pier	See Note 1
Circuit 15	Receptacle - Bottom Elevator Shaft	400

Note 1: Meggering circuit would have required extensive disassembly of equipment.

Note 2: Circuit could not be de-energized for testing.

FEEDER MEGGERING

Incoming High Voltage Feeders to Bridge

Transformer Room

Line	Megger Reading
1	1,000 megohms
2	1,000
3	1,000

Main Feeders to South Tower Panelboard

Line	Megger Reading
1	500 megohms
2	500
3	1,000

CONTROL BUS MEGGERING

RL = Rail Lock   SL = Span Lock

Wire No.	Limit Switch	Pier	Megger Reading
C_1 - 399	RL Closed	North	500 K ohms
C_1 - 411	RL Open	North	25 meg
C_1 - C105	RL Closed	South	500 K ohms
C_1 - C106	RL Open	South	30 meg
431	NW SL Closed	North	500 meg
C107	SW SL Closed	South	500 K ohms
C108	SW SL Open	South	40 meg
439	NW SL Open	North	1.6 meg
C_3 - 416	RL Closed	North	1.6 meg
C_3 - 419	RL Open	North	20 meg
C_3 - C120	RL Closed	South	1.7 meg
C_3 - C121	RL Open	South	30 meg
442-442A	NW SL Open	North	50 meg
C123	SW SL Open	South	50 meg
C122	SW SL Closed	South	1.6 meg

MEGGER CONTROL BUS

C_1 to Ground	Normal Bus	2 meg ohms
C_3 to Ground	Emergency Bus	4 meg ohms

COOPER ENERGY SERVICES

Service Representative's Report

H. T. Blake Jr., Service Repr.

May 11, 1984

MOJESKI/ARMY CORPS OF ENGINEERS

Buzzards Bay, Maine

40-SX-6

15496

Brief reason for report - Inspection of engine condition.

May 7 - Travel by company car enroute to job location.

May 8 - At job location, met customer, Lance Borden. John Thompson of CES was helping me on inspection.

We removed lower block covers to inspect crankcase. Found no outstanding visual problems. Barred engine over and checked liners on bottom half. All were smooth, no sign of any scores. Rolled engine by hand and checked timing chain and oil pump drive gear, both looked good. Adjusted chain tension to specification. Took crankshaft web deflection readings on all throws, all were in specification, readings are attached. We had access to previous reading of twelve years ago and the two readings were much the same.

We adjusted the fan drive belts as they were too tight and causing a high positive deflection reading at #1 throw. The crankshaft thrust was .005" and the camshaft thrust was .010", the cam lobes all looked like new. Put covers back on so we could run engine tomorrow.

May 9 - Started engine and let warm up so we could see engine under load. They lowered and raised the bridge, engine pulled load well. Tried to check overspeed shutdown, found it would not move. One of the drives was worn out and will have to be replaced. Until it is repaired there is no overspeed protection on this engine. I wrote down part numbers of defective pieces so they can be ordered by the customer. Set and checked alarms for low oil pressure, high water temperature and high oil temperature, no shutdowns for these.

Other possible problems we found were the emergency start and stop valves were painted over and were stuck. If control power was lost the engine could be operated using these emergency valves manually. The handle for rotating the lube oil strainer was missing, this needs to be installed so operator can clean strainer, it is supposed to be turned quite often when engine is running. For operator convenience, the thermometer could be replaced with ones easier to see and read. Also I feel the engine water jacket thermostat was not working properly as 140 degrees F. was as high a temperature we could reach on water out of engine. We set the intake and exhaust valve tappets at .015" intake, .018" exhaust, set some of air start valves that were out of adjustment.

Generally, the engine was in good shape and showed it has had good care. The only urgent problem found was with the overspeed trip. The three parts to renew it are as follows:

BM-233
BM-3596
BM-5694

We finished our inspection so customer released us.

May 10-11 - Returned to Springfield, Ohio.

/m

CHART OF CRANKSHAFT DISTORTION INDICATOR READINGS

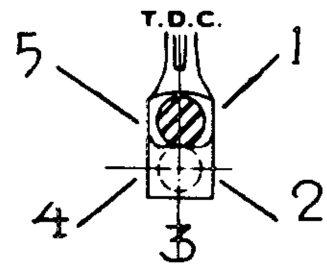
ENGINE SERIAL NO.	MODEL	CUSTOMER OR OWNER
15496	40-SX-6	MoJeski / Corp of Engeers

Position	CYLINDER No. 1	CYLINDER No. 2	CYLINDER No. 3	CYLINDER No. 4	CYLINDER No. 5	CYLINDER No. 6	CYLINDER No. 7	CYLINDER No. 8
	POSITION READING INDICATE (+) OR (−)	POSITION READING INDICATE (+) OR (−)	POSITION READING INDICATE (+) OR (−)	POSITION READING INDICATE (+) OR (−)	POSITION READING INDICATE (+) OR (−)	POSITION READING INDICATE (+) OR (−)	POSITION READING INDICATE (+) OR (−)	POSITION READING INDICATE (+) OR (−)
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	+.0005	+.0004	0000	-.0002	-.0007	-.0004		
3	+.0004	+.0006	+.0002	-.0004	-.0006	+.0005		
4	-.0003	0000	0000	+.0002	+.0004	+.0017		
5	-.0005	-.0001	-.0001	+.0002	+.0003	+.0012		

DIRECTION OF ROTATION FACING FLYWHEEL

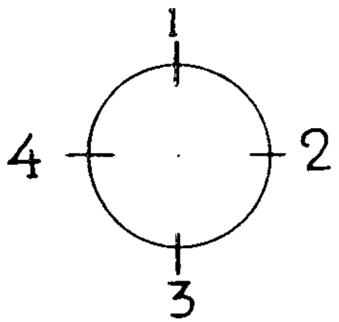
INDICATE WITH "X" ALL THAT APPLIES TO NO. 1 CYL.

- ☐ CLOCKWISE
- ☒ COUNTERCLOCKWISE
- ☒ GOVERNOR END
- ☐ FLYWHEEL END
- ☒ CAM-DRIVE END



COUPLING ALIGNMENT

BETWEEN ENGINE OR GEAR BOX AND ______________



ANGULAR		PARALLEL	
POSITION	READING INDICATE (+) OR (−)	POSITION	READING INDICATE (+) OR (−)
1		1	
2		2	
3		3	
4		4	

GENERATOR AIRGAP

FLYWHEEL SIDE

PEDESTAL BRG. SIDE

ENGINE HIGH ____ LOW ____

RADIUS OF COUPLING AT INDICATOR READING ______________

FORM NO. [illegible]-A MANUFACTURED BY ______ MODEL ______________

MANUFACTURED BY ______________

GENERATOR S/N ______________

RECORDED BY Tom Blake DATE 5-8-84

John Thompon

**Westinghouse
Electric Corporation**

10 California Avenue
Box 1060
Framingham Massachusetts 01701
(617) 237 6950

June 25, 1984

Modjeski & Masters
P.O. Box 2345
Harrisburg, PA 17105

ATTENTION: Joseph J. Scherrer, P.E.

RE: INSPECTION AND CONDITION REPORT
Vertical Lift Railroad Bridge
Cape Cod Canal, Buzzards Bay, MA — Westinghouse BSEN-286

Enclosed is our Engineer's report of the tests and work performed at the above facility.

This report is for your information and files.

If you have any questions do not hesitate to call.

Thank you for the opportunity to be of service to you.

Very truly yours,

Eddy Sousa

EDDY SOUSA
Service Coordinator
New England Engineering Service

Westinghouse Electric Corporation

Industry Services Divisions

Apparatus Service Division

Apparatus Service Report

ISSUING OFFICE: Westinghouse Electric Corp.	JOB # BSEN-286	DATE WRITTEN 5/2/84
10 California Avenue	CUSTOMER Modjeski & Masters	
Framingham, MA ZIP 01701	ADDRESS 424 Trapelo Road	
New England Engineering Service PHONE	Waltham, MA 02254 ZIP	
REPORT # INDICATE IF FINAL ☐	CUSTOMER ORDER AND DATE	
SUBMITTED BY S. Wilson/S. Frazier/ W. Murch	REPORTED TO	DATE REPORTED ON JOB
TITLE Field Engineer LOCATION Framingham	TITLE	PHONE

COVER FOLLOWING POINTS ON EACH JOB AND NUMBER PARAGRAPHS EXACTLY AS SHOWN

1. APPARATUS IDENTIFICATION	2. LENGTH OF TIME IN SERVICE AND APPLICATION	3. COMPLAINT OR PROBLEM	4. AS FOUND CONDITIONS	5. WORK DONE AND STATUS OF JOB THIS REPORT	6. LIST MATERIAL TO BE ORDERED INDICATE ANY FURTHER WORK NECESSARY

Upon arrival, the Bridge Controller, Lance Borden and myself opened the two General Electric Air Break High Voltage Disconnects so work could be performed on the 15 KVA and 150 KVA transformer banks which these switches fed. In order for work to be performed on the switches, the line side of both switches needed to be de-energized. The Army Corp. of Engineers line crew upon request of Bridge Controller opened the knife blade disconnects on top of utility pole adjacent to emergency generator building.

The following is a general summary of condition on each piece of apparatus.

1. 5 KV General Electric air break, load break disconnect switch feeding 15 KVA bank. This switch was in good condition with only the door interlock inoperative. Apparently the operator of the switch tried to close switch with door open forcing mechanism and breaking interlock. The interlock was repaired on site and is now operative.

   Main blades were arc free as well as flicker blades and arc chutes indicating switch has not been opened under heavy load. Enclosure, insulating bushings and mechanism were found to be in excellent condition, although line side cables were found slightly loose and were tightened.

Fuses were ductored with a digital low resistance Ohmmeter. The closeness of readings to each other indicate that any one fuse has probably never been stressed close to its limit. Insulation resistance of switch is also good.

2. 5 KV General Electric air break, load break disconnect switch feeding 150 KVA bank. This switch was found in excellent condition. Main blades were arc free as well as flicker blades and arc chutes. Enclosure, bushings, mechanism were in excellent condition. Line side cables were also found loose on this switch and were re-tightened. The fuses were also ductored and readings indicate equal electrical integrity between fuses.

   The contact resistance on this switch as well as the resistance off the switch feeding the 15 KVA transformer load is good as detected with a digital low resistance Ohmmeter. These resistances measured in micro-ohms are good although contact resistance should be brought down to the 10-20 micro-ohm range across the entire switch by tightening the moving main contact gap.

   The insulation resistance of the entire switch is excellent.

3. The 15 KVA transformer bank was found to be in fair condition due to the fact that there was cracked and rotting insulation on the high side cables of the middle and right transformers. Aside from this problem, the cosmetic condition of this bank is excellent considering its age.

Apparatus Service Report

The oil samples were sent to Westinghouse Lab to be analyzed for seven parameters. All the parameters of the oil in this bank meet the classifications of service aged oil as set up by Sharon Transformer Division. This oil displays excellent dielectric, good moisture and power factor levels as well as neutralization and interfacial tension. This oil is suitable for continued use as stated in the oil analysis report.

The oil level in these transformers is unknown. This is due to the fact that these transformers do not have sight glasses. It is recommended that the transformers be removed from service, covers removed and level visually checked. It is also recommended that the high voltage cable on transformers be repaired in the near future.

4. The 150 KVA bank was found in good physical condition with no oil leaks present at the time of inspection.

   The oil in this bank of transformers has excellent dielectric strength, low moisture content and a good power factor. This oil has poor acid content (neutralization) and interfacial tension. This possibly suggests contamination or deterioration. Westinghouse Sharon, PA suggests reclaiming of oil which is a filtering process utilizing Fuller's Earth. Due to volume of oil in these three transformers, I suggest simply to remove oil and properly dispose and refill with new oil.

   I also feel these transformers can be considered for continued service for a short to medium length of time due to the fact that they have good dielectric, moisture and power factor parameters.

Apparatus Service Report

The oil level in these units through visual inspection of sight glass appear to be low. If oil is not changed out as suggested, this level should be brought up to the 25 degree centigrade mark on sight glass with make-up oil.

Both banks of transformers are within federal register definitions of classified non-PCB fluids. All transformers display less than 50 PPM PCB.

Attached to this inspection report for this apparatus are laboratory reports containing results of oil analysis and PCB analysis. Also attached are explanatory definitions of "Significance of Tests" and "Classifications of Service Aged Oils" for your review. I am also enclosing six (6) certified non-PCB stickers which are to be affixed to each transformer.

WESTINGHOUSE ENGINEERING SERVICE

HIGH VOLTAGE DISCONNECT SWITCH REPORT

Job # BSEN-286

Customer Modjeski & Masters

Station Location Buzzards Bay R.R. Bridge/Cape Cod Canal

Switch Mfgr. General Electric

Switch Identification Type SE - Air Break, Load Break Switch

Voltage Rating 4800 Volt **Current Rating** 600 Amp

Fuse Mfgr. S&C Power **Size** 400 A **Style #** 86641R1

A. VISUAL INSPECTION

1. Enclosure	OK
2. Insulators and Bushings	OK
3. Bus	*Loose
4. Disconnect Blades, Condition	OK
5. Arc Chutes	OK
6. Mechanism, Linkage	OK
7. Switch Operation	OK
8. Key Interlock Switch, Operation	**Inoperative
9. Cleanliness	OK

10. **REMARKS** *Line side cable connections found loose and were tightened.
**Key interlock repair on site.

B. ELECTRICAL TESTS - (Megohms)

	(A) Left Phase	(B) Center Phase	(C) Right Phase
1. Contact Resistance	55	51	46
2. Insulation Resistance	A - B 2000	B - C 2000	C - A 2000
	A - G 2000	B - G 2000	C - G 2000
Across Open Contacts	A 2000	B 2000	C 2000

3. **REMARKS** Fuses ductored at 8.31 Megohms, 8.25 Megohms, 8.30 Megohms, A, B, C, respectively.

BY S. Frazier **DATE** 5/2/84

BSE-DS-1-16

WESTINGHOUSE ENGINEERING SERVICE

HIGH VOLTAGE DISCONNECT SWITCH REPORT

Job # BSEN-286

Customer Modjeski & Masters

Station Location Buzzards Bay R.R. Bridge/Cape Cod Canal

Switch Mfgr. General Electric

Switch Identification Type SE - Air Break, Load Break. 150 KVA

Voltage Rating 4800 Volt Current Rating 600 Amp

Fuse Mfgr. S&C Power Size 400 A Style # 86641R1

A. VISUAL INSPECTION

1. Enclosure OK
2. Insulators and Bushings OK
3. Bus OK
4. Disconnect Blades, Condition OK
5. Arc Chutes OK
6. Mechanism, Linkage OK
7. Switch Operation OK
8. Key Interlock Switch, Operation OK
9. Cleanliness OK
10. REMARKS Line side connections found loose and were tightened.

B. ELECTRICAL TESTS - (Megohms)

	(A) Left Phase	(B) Center Phase	(C) Right Phase
1. Contact Resistance	50	49	47
2. Insulation Resistance	A - B 2000	B - C 2000	C - A 2000
	A - G 2000	B - G 2000	C - G 2000
Across Open Contacts	A 2000	B 2000	C 2000

3. REMARKS Fuses ductored at 596 Megohms, 605 Megohms, 600 Megohms, A, B, C, respectively.

BY S. Frazier DATE 5/2/84

BSE-DS-1-16

WESTINGHOUSE ELECTRIC CORPORATION

INDUSTRY SERVICES DIVISIONS LABORATORY
PITTSBURGH, PENNSYLVANIA
TRANSFORMER INSULATING LIQUID ANALYSIS
OIL ANALYSIS

WESTINGHOUSE ELECTRIC CORPORATION
P.O.BOX 1060
10 CALIFORNIA AVENUE
FRAMINGHAM, MA 01701

DATE TESTED: 5-17-84
CUSTOMER: MODJESKI & MASTERS
LABORATORY NO.: 84-520
P. O. NO.: BSEN28602

	1	2	3	4
TRANSFORMER SER. NO.	5134237	51133513	5092960	5194667
SOURCE OF SAMPLE	MAIN TANK BOTTOM	MAIN TANK BOTTOM	MAIN TANK BOTTOM	MAIN TANK BOTTOM
ANALYSIS RESULTS:				
GENERAL CONDITION	AMBER CLEAR	AMBER CLEAR	YELLOW CLEAR	YELLOW CLEAR
DIELECTRIC STRENGTH - KV(60 HZ @ 25'C)	51.8	48.6	49.6	50.4
POWER FACTOR - PERCENT(60 HZ @ 25'C)	.175	.220	.028	.034
INTERFACIAL TENSION - DYNES/CM	19.0	18.5	24.2	22.8
NEUTRALIZATION NO. - MG KOH/GRAM	.437	.440	.139	.171
COLOR - ASTM D-1500	3.0	3.0	1.5	1.5
MOISTURE - PPM	22	23	12	24

THE FOLLOWING SUGGESTIONS AND REMARKS ARE IN COMPLIANCE WITH RECOMMENDED VALUES ESTABLISHED BY (W) SHARON TRANSFORMER DIVISION.

1. SUGGEST RECLAIMING DUE TO LOW INTERFACIAL TENSION AND HIGH NEUTRALIZATION NUMBER.
2. SUGGEST RECLAIMING DUE TO LOW INTERFACIAL TENSION AND HIGH NEUTRALIZATION NUMBER.
3. SAMPLE IS GOOD FOR CONTINUED USE.
4. SAMPLE IS GOOD FOR CONTINUED USE.

I HEREBY CERTIFY THAT THIS REPORT IS A TRUE RECORD BASED ON LABORATORY TESTS PERFORMED IN ACCORDANCE WITH ALL APPLICABLE, CURRENT A.S.T.M. METHODS.

TECHNICIAN______________________________ APPROVED HC MacDonald

It is recommended that a dissolved gas analysis be performed every six months to determine what gases are present in the oil and what changes, if any, have occurred. Early detection of combustible gases may indicate a possible malfunction in transformer. Once diagnosed, an orderly maintenance plan can be scheduled thereby avoiding unexpected interruptions.

REPORT DATE: 05/17/84

WESTINGHOUSE ELECTRIC CORPORATION

INDUSTRY SERVICES DIVISIONS LABORATORY
PITTSBURGH, PENNSYLVANIA
TRANSFORMER INSULATING LIQUID ANALYSIS
OIL ANALYSIS

WESTINGHOUSE ELECTRIC CORPORATION
P.O.BOX 1060
10 CALIFORNIA AVENUE
FRAMINGHAM, MA 01701

DATE TESTED: 5-17-84
CUSTOMER: MODJESKI & MASTERS
LABORATORY NO.: 84-520
P. O. NO.: BSEN28602

	5	6
TRANSFORMER SER. NO.	5092998	5133514
SOURCE OF SAMPLE	MAIN TANK BOTTOM	MAIN TANK BOTTOM
ANALYSIS	**RESULTS:**	
GENERAL CONDITION	YELLOW CLEAR	AMBER CLEAR
DIELECTRIC STRENGTH - KV(60 HZ @ 25'C)	41.6	51.0
POWER FACTOR - PERCENT(60 HZ @ 25'C)	.036	.130
INTERFACIAL TENSION - DYNES/CM	23.8	18.8
NEUTRALIZATION NO. - MG KOH/GRAM	.169	.431
COLOR - ASTM D-1500	1.5	2.5
MOISTURE - PPM	19	18

THE FOLLOWING SUGGESTIONS AND REMARKS ARE IN COMPLIANCE WITH RECOMMENDED VALUES ESTABLISHED BY (W) SHARON TRANSFORMER DIVISION.

5. SAMPLE IS GOOD FOR CONTINUED USE.
6. SUGGEST RECLAIMING DUE TO LOW INTERFACIAL TENSION AND HIGH NEUTRALIZATION NUMBER.

I HEREBY CERTIFY THAT THIS REPORT IS A TRUE RECORD BASED ON LABORATORY TESTS PERFORMED IN ACCORDANCE WITH ALL APPLICABLE, CURRENT A.S.T.M. METHODS.

TECHNICIAN______________________________ APPROVED HC MacDonald Jr ______________________________

It is recommended that a dissolved gas analysis be performed every six months to determine what gases are present in the oil and what changes, if any, have occurred. Early detection of combustible gases may indicate a possible malfunction in transformer. Once diagnosed, an orderly maintenance plan can be scheduled thereby avoiding unexpected interruptions.

REPORT DATE: 05/17/84

WESTINGHOUSE ELECTRIC CORP
INDUSTRY SERVICES DIVISIONS
ANALYTICAL AND TESTING LABORATORY

POLYCHLOROBIPHENYLS ANALYSIS REPORT

ESO/ASP:BECKLEY ESO LAB#:84-520 DATE RECEIVED: 05/07/84
CUSTOMER...MODJESKI & MASTERS
P.O.#...BSEN28602
****

SAMPLE ID: 5134237
DATE TESTED= 05/10/84
AROCHLOR 1242= 0 PPM
AROCHLOR 1254= 24 PPM
AROCHLOR 1260= 0 PPM

TOTAL = 24 PPM

COMMENT CODE= R...SEE SYMBOL SHEET
SAMPLE #= 1

SAMPLE ID: 51133513
DATE TESTED= 05/10/84
AROCHLOR 1242= 0 PPM
AROCHLOR 1254= 5 PPM
AROCHLOR 1260= 9 PPM

TOTAL = 14 PPM

COMMENT CODE= R...SEE SYMBOL SHEET
SAMPLE #= 2

SAMPLE ID: 5092960
DATE TESTED= 05/10/84
AROCHLOR 1242= 0 PPM
AROCHLOR 1254= 1 PPM
AROCHLOR 1260= 0 PPM

TOTAL = 1 PPM

COMMENT CODE= R...SEE SYMBOL SHEET
SAMPLE #= 3

SAMPLE ID: 5194667
DATE TESTED= 05/10/85
AROCHLOR 1242= 0 PPM
AROCHLOR 1254= 1 PPM
AROCHLOR 1260= 0 PPM

TOTAL = 1 PPM

COMMENT CODE= R...SEE SYMBOL SHEET
SAMPLE #= 4

NOTE THE RESULTS REPORTED HERE ARE OBTAINED BY THE METHODS RECOMMENDED BY THE U.S. EPA. THE QUALITY ASSURANCE OF THE DATA MEETS THE STANDARDS OF THE U.S. EPA.

****

ENGINEER........................../TECH. J. P. Fitzgerald

APPROVED BY: H.C. MacDonald Jr.
DATE 05/11/1984

WESTINGHOUSE ELECTRIC CORP
INDUSTRY SERVICES DIVISIONS
ANALYTICAL AND TESTING LABORATORY

POLYCHLOROBIPHENYLS ANALYSIS REPORT

ESO/ASP:BECKLEY ESO LAB#:84-520 DATE RECEIVED: 05/07/84
CUSTOMER...MODJESKI & MASTERS
P.O.#...BSEN28602

****

SAMPLE ID: 5092998
DATE TESTED= 05/10/84
AROCHLOR 1242= 0 PPM
AROCHLOR 1254= 0 PPM
AROCHLOR 1260= 0 PPM

TOTAL = 0 PPM

COMMENT CODE= L...SEE SYMBOL SHEET
SAMPLE #= 5

SAMPLE ID: 5133514
DATE TESTED= 05/10/84
AROCHLOR 1242= 0 PPM
AROCHLOR 1254= 13 PPM
AROCHLOR 1260= 12 PPM

TOTAL = 25 PPM

COMMENT CODE= R...SEE SYMBOL SHEET
SAMPLE #= 6

NOTE THE RESULTS REPORTED HERE ARE OBTAINED BY THE METHODS RECOMMENDED BY THE U.S. EPA. THE QUALITY ASSURANCE OF THE DATA MEETS THE STANDARDS OF THE U.S. EPA.

****

ENGINEER......................../TECH. J. B. Fitzgerald
APPROVED BY: K. MacDonald
DATE 05/11/1984

****

WESTINGHOUSE ELECTRIC CORP
INDUSTRY SERVICES DIVISIONS
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POLYCHLOROBIPHENYLS ANALYSIS REPORT

ESO/ASP:BECKLEY ESO LAB#:84-520 DATE RECEIVED: 05/07/84
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P.O.#...BSEN28602
****

SYMBOL DEFINITION SHEET FOR PCB REPORTS

(A)...AROCHLOR 1254 IS SUSPECTED OF BEING PRESENT AND IS INCLUDED IN THE 1260 AMOUNT

(B)...AROCHLOR 1260 IS SUSPECTED OF BEING PRESENT IN SMALL AMOUNTS AND IS INCLUDED IN THE 1254 AMOUNT

(C)...AROCHLOR 1254 IS SUSPECTED OF BEING PRESENT IN SMALL AMOUNTS AND IS INCLUDED IN THE 1242 AMOUNT

(D)...AROCHLOR 1260 IS SUSPECTED OF BEING PRESENT IN SMALL AMOUNTS AND IS INCLUDED IN THE 1242 AMOUNT

(E) &(F)...BECAUSE OF THE +/- ANALYTICAL ACCURACY, THE SAMPLE(S) SHOULD BE CONSIDERED OVER (50PPM FOR E & 500PPM FOR F)

(*)...INFRARED SPECTRA CONFIRMS THIS SAMPLE IS ASKAREL(400,000 TO 600,000PPM)

(X)...INTERFERENCE IS PRESENT

(N)...SAMPLE RESULTS AS STATED

(L)...LESS THAN THE DETECTABLE LIMIT OF 1 PPM

(R)...CORRECTED FOR RECOVERY

(RS)..CORRECTED BY RECOVERY OF A KNOWN ADDITION OF PCB TO SAMPLE

CLASSIFICATION OF SERVICE AGED TRANSFORMER OILS

It is virtually impossible to attempt to place a rigid interpretation on the condition of a specific oil from one test or one test result, and from this to make recommendations. However, certain groups of results will produce patterns which can then be used to establish a picture of the oil condition. Industry experience has developed a classification of four classes of service-aged transformer oils.

GROUP I — This group contains oils that are satisfactory for continued use.

GROUP II — This group contains oils that require only minor reconditioning to continue in service.

GROUP III — This group contains oils that are in poor condition. These should be reclaimed or disposed of depending upon economic consideration.

GROUP IV — This group contains oils in such poor condition that it is technically advisable only to dispose of them.

Reference here to "reconditioning" and "reclaiming" means:

RECONDITIONING is the removal of water and solids from oil. Typical equipment includes several types of filters, centrifuges, and vacuum dehydrators.

RECLAIMING is the removal of deterioration products and usually is accomplished by use of reclaiming processes involving fullers' earth alone or in combination with certain chemicals.

The following table lists the various recommended values for consideration of an oil in a specific classification:

	GROUP I	GROUP II	GROUP III	GROUP IV
TEST	OIL FOR CONT'D. SERVICE	OILS TO BE RECONDITIONED	OILS TO BE RECLAIMED	OILS TO BE SCRAPPED
Dielectric Breakdown, KV	28	Less than 28	Low	Low
Neutralization Number mg KOH per gr. of oil	up to .25	.25-.35	.35-.5	.5 & above
Interfacial Tension dynes per cm.	21	21	18	16
Power Factor, 60 HZ, 25^{o} C, percent	1.0	1.2	2.0	5.0
Moisture Content, ppm	25	35	above 35	--

No oil should be considered for continuing service if the dielectric strength cannot be brought up to at least 28KV or if the moisture content cannot be held below 35 ppm.

Reprinted from: Protective Maintenance of Transformers by Gas-Oil Analysis. Published by Westinghouse - Sharon Transformer Division, Sharon, Pennsylvania. Publication No. M7247

Significance of Test

1. **Dielectric Breakdown ASTM D-877, D-1816** — The dielectric breakdown voltage is an important measurement of the electrical stress which an insulating liquid can withstand without failure. It is measured by applying a voltage between two electrodes under prescribed conditions under the liquid. It also serves as an indication of the presence of contaminants, particularly moisture and conducting particulate matter.

   Dielectric testing should be made as described in the ASTM procedures. ASTM D877 specifies a test cup equipped with one-inch diameter vertical disc electrodes spaced 0.100 inch apart and is reported as the standard dielectric test value. ASTM D-1816 specifies a test cup equipped with spherical electrodes spaced 0.080 inch apart. This cup includes a stirrer and is sensitive to small amounts of contaminants and is therefore primarily suitable for use with new oils.

2. **Neutralization Number, ASTM D-974** — The neutralization number is the number of milligrams of potassium hydroxide required to neutralize the acid in one gram of the oil. It measures the acid content of the oil. With service aged oils it can be used as an indicator of the presence of contaminants. The neutralization number is most important in indicating chemical change of deterioration of the oil or in chemical change of additives. It is a guide for determining when oil should be replaced or reclaimed when the results are confirmed or supported by other test data.

3. **Interfacial Tension, ASTM D-971** — The interfacial tension between the insulating oil and water is a measure of the molecular attractive force between the unlike molecules and is expressed in dynes per centimeter. This test provides a means of detecting soluble polar contaminants and products of deterioration. Soluble contaminants or oil-deterioration products generally decrease the interfacial tension value.

4. **Power Factor, ASTM D-924** — The power factor is the ratio of the power dissipated in the oil in watts to the product of the effective voltage and current in voltamperes, when tested with a sinusoidal field under prescribed conditions. A high power factor value is an indication of the presence of contaminants or deterioration products.

5. **Color, ASTM D-1500** — The primary significance of color is to observe a rate of change from previous samples of oil from the same transformer. Noticeable darkening in short periods of time indicate either contamination or deterioration of the oil. A darkening color, with no significant change in neutralization value or viscosity, usually indicates contamination with foreign materials. The color of an insulating oil is determined by means of transmitted light and is expressed by a numerical value based on comparison with a series of color standards.

6. **Pour Point, ASTM D-97** — The pour point is the temperature at which insulating oil will just flow under prescribed conditions. The pour point is useful in determinging the type of equipment in which a given oil can be used, but has little significance as far as contamination or deterioration are concerned.

7. **Specific Gravity, ASTM D-1298** — The specific gravity of insulating oil is the ratio of the weights of equal volumes of oil and water at 15.56°C(60°F). The specific gravity may be pertinent in determining the suitability for use in specific application.

8. **Viscosity, ASTM D-88** — The viscosity of insulating oil is its resistance to uniformly continuous flow without turbulence, inertia or other forces. It is usually measured by timing the flow of a given quantity of oil under controlled conditions. A marked viscosity increase accompanied by an increasing neutralization number and darkening color, could also indicate deterioration of the oil due to oxidation.

9. **Moisture Content, D-1533** — The presence of free water may be observed by visual examination in the form of separated droplets or as a cloud dispersed throughout the oil. Water in solution is normally determined by physical or chemical means. It is measured in parts per million. Water invariably causes decreased dielectric strength of the oil.

WESTINGHOUSE ENGINEERING SERVICE

TRANSFORMER CONDITION REPORT

Job #BSEN-286

Customer: Modjeski & Masters

Location: Buzzards Bay R.R. Bridge/Cape Cod Canal

Circuit or Application: 4160 Volt Bank

Mfgr: General Electric . Type: H Form KF Serial: 5133514 5134237 5133513

Rating KVA: 150 KVA Ea. Pri. V.: 2400/4160 Y Sec. V.: 240/480

Single Phase: 3 Single Three Phase: ____ Auto: ____

Pri. Connection: 4160 Sec. Connection: 480

Pri. Taps: H1 - H2 Sec. Taps: X1-X4 Tap Setting: ____

Dry Type: ____ Oil Type: X Inerteen Type: ____

A. VISUAL AND MECHANICAL INSPECTION

1.	Check Primary, Secondary and Ground Connections	OK
2.	Clean and Inspect Porcelain Insulators	OK
3.	Check Tap Connections and Tap Changer	N/A
4.	Vacuum, Clean or Use Air to Remove Dust-Dry Type	OK
5.	Inspect Bushing Clamps and Gaskets	OK
6.	Inspect Cover and Hand-Hole Gasket Seals	OK
7.	Check for Oil Leaks and External Damage to Radiators	OK
8.	Inspect for Gas Leaks-Inert Air Type Units	N/A
9.	Check Liquid Level	*
10.	Check Accessories for Condition and Operation	N/A

B. ELECTRICAL TESTS - (Megohms)

1.	Insulating Resistance	Hi To Low & Ground	100+
		Low To Hi & Ground	100+
		Hi-Low To Ground	100+

2. Insulating Liquid Dielectric Test KV: See Analysis Acidity: -

Remarks: *Liquid level low but not dangerous. Should top off level with make-up oil.

By: S. Wilson/S. Frazier/W. Murch Date: 5/2/84

WESTINGHOUSE ENGINEERING SERVICE

TRANSFORMER CONDITION REPORT

Job #BSEN-286

Customer: Modjeski & Masters

Location: Buzzards Bay R.R. Bridge/Cape Cod Canal

Circuit or Application: 15 KVA Bank - Normal Lighting

Mfgr: General Electric | Type: H Form N. | Serial: Bank 5092998 / 5194667 / 5092960

Rating KVA: 15 KVA Ea. | Pri. V.: 2400/4160 Y | Sec. V.: 120/240V

Single Phase: 3 Single Ø | Three Phase: ______ | Auto: ______

Pri. Connection: 4160V | Sec. Connection: 120/240

Pri. Taps: H1 - H2 | Sec. Taps: X1 - X4 | Tap Setting: ______

Dry Type: ______ | Oil Type: X | Inerteen Type: ______

A. VISUAL AND MECHANICAL INSPECTION

1.	Check Primary, Secondary and Ground Connections	OK
2.	Clean and Inspect Porcelain Insulators	OK
3.	Check Tap Connections and Tap Changer	N/A
4.	Vacuum, Clean or Use Air to Remove Dust-Dry Type	OK
5.	Inspect Bushing Clamps and Gaskets	OK
6.	Inspect Cover and Hand-Hole Gasket Seals	OK
7.	Check for Oil Leaks and External Damage to Radiators	OK / N/A
8.	Inspect for Gas Leaks-Inert Air Type Units	N/A
9.	Check Liquid Level	No Sight Glass
10.	Check Accessories for Condition and Operation	N/A

B. ELECTRICAL TESTS - (Megohms)

1.	Insulating Resistance	Hi To Low & Ground	100+
		Low To Hi & Ground	100+
		Hi-Low To Ground	100+

2. Insulating Liquid Dielectric Test KV: See Analysis | Acidity: -

Remarks: Loose rotting insulation on cable at XFMR. Connection on H2 middle and H1 right.

By: S. Wilson/W. Murch/S. Frazier | Date: 5/2/84

APPENDIX B

MECHANICAL EQUIPMENT TESTS

Trunnion Bearing Report from Bearing Manufacturer

Oil and Grease Analysis by Ana-Laboratories, Inc.

Plumbing Inspection by Jackson Plumbing and Heating, Inc.

TORRINGTON
Part of worldwide Ingersoll-Rand

District Office
North American Sales

The Torrington Company
71 McMurray Road
Pittsburgh, PA 15241
(412) 831-5454

Mr. Milton C. Stafford, P.E.
39 Union Avenue
Bala Cynwd, Pa. - 19004

July 20, 1984

Dear Mr. Stafford:

On May 7th and 8th, I was present, at your request, on the Buzzard's Bay Railroad Bridge in Cape Cod, Massachusetts. While there I inspected 2 main bearing assemblies (U-412Q) used on the lift sheaves. The main bearing assembly is composed of a cylindrical roller bearing with a spherical outer race. This cylindrical bearing is mounted in a pillow block in conjunction with a thrust bearing which is piloted on the outboard end cover.

The following is a description of the above mentioned inspection. The first assembly inspected was in the South Tower, the West-most block. The end cover that contains the thrust bearing was removed for ease of inspection. Initial examination revealed metal debris in the grease. The amount of the debris present warranted cleaning the entire bearing to determine the extent of the damage. This cleaning was done using kerosene which completely removed all the grease and contaminants from the bearing. I was then able to do a thorough inspection of the two bearings in this block.

Inspection of the cylinder roller bearing revealed that all bearing components still displayed their original grind pattern. There was no indication of wear and no apparent damage from the debris. The diametrical clearance was measured and found to be .011".

The thrust bearing was removed and cleaned. It was marked serial no. 16. The original grind pattern could be seen on both the flat washer and the spherical washer. The rollers all appeared to be in good condition. There were a couple of rollers that exhibited water etching. This water etching was superficial and polished off with 240 grit emery paper.

The end cover of the pillow block was the reason for the metal debris in the bearing. The top half of the thrust bearing pilot that extends out from the center of the end cover had been worn away. This wear appears to have come from the flat washer of the bearing dropping down when the thrust load was in the opposite direction. The wear was on the top 180° of the pilot, back approximately 3/8 of an inch and had taken approximate 3/8 of an inch off the diameter.

The second bearing assembly inspected was the North Tower, East Block. The cylindrical bearing was found to be full of grease. There were no contaminants in the grease so it was not cleaned. The bearing was throughly examined with a wire. No signs of damage were found. The diametrical clearance of the bearing was measured and found to be .014".

The thrust bearing in this block was also removed and thoroughly cleaned. The flat washer exhibited an excellent contact pattern with no abnormal wear. The spherical washer had a straw color discoloration where the innermost set of rollers also exhibited the straw color discoloration. A few of the rollers again had superficial water marks which were polished with 240 grit emery cloth.

Approximately two weeks after my inspection you sent me 8 packages containing debris that had been removed during inspection of the remaining 14 blocks. I, in turn, sent these to our Engineering Department so they could be checked for material content. By using a scanning electron microscope it was determined that the material in all 8 cases was end cover material and not bearing material.

In a telephone conversation you mentioned that quite a few thrust bearings displayed heat discoloration. If the bearings have seen excessive heat it will soften the components leading to an early failure. Because of this I would recommend replacement of any of the thrust bearings that exhibit the straw or blue discoloration due to heat.

If we can be of any further assistance to you in the future please do not hesitate to contact us.

Very truly yours,

Bill Slusarczyk

Bill Slusarczyk
Service Engineer

ak

WHERE AN OIL COOLS & LUBRICATES · WE PLAY A VITAL ROLE IN MAINTENANCE, MANAGEMENT & FINANCIAL DECISION

Ana-Laboratories, Inc. (A-L,I)

LAB
111 Harding Avenue
Bellmawr, N. J. 08031
(609) 931-0011
(800) 257-7896

6/8/84

MILTON C.STAFFORD P.E
39 UNION AVENUE
BALA, CYNWYD, PA. 19004

Toll Free (800) 257-7896

ATTN: MR. MILTON STAFFORD,P.E.

SUMMARY REPORT ON OIL ANALYSIS FOR 20 UNITS:

TB8S, TB7N, TB8N, GREASE; NRAILLO, SRAILLO, GEAR OIL; TB2N, TB1S, TB4S, TB5N, TB6N, TB6S, TB5S, TB2S, TB3S, TB7S, TB1N, TB3N, TB4N, GREASE; SSPANLO, NSPANLO, GEAR OIL.

UNITS NEEDING IMMEDIATE ATTENTION - TAKE CORRECTIVE ACTION:

None.

UNITS NEEDING CLOSE WATCH OR CORRECTIVE ACTION:

None.

UNITS SHOWING MODERATE WEAR:

TB8S, GREASE. WEAR METALS - gear/bearing (copper) -moderately high (abnormal).

TB7N, TB8N, GREASE. WEAR METALS - gear/bearing (copper) Lead wear may be from bearing ,bushing or shims/spacer,etc. -moderately high (abnormal).

NRAILLO, GEAR OIL. WEAR METALS - gear/bearing (iron) -MILDLY ABOVE NORM (ACCEPTABLE). . LUBE CONTAM.- Combined contaminants (various TYPES)- -ACCEPTABLE. . Continue scheduled maint. program. Resample per your schedule. Oil drain may be extended.

SRAILLO, GEAR OIL. WEAR METALS - gear/bearing (iron) -moderately high (abnormal). . LUBE CONTAM.- Combined contaminants (various TYPES)- -ACCEPTABLE. . Advise monitoring. Since lube contaminants are normal,this wear is attributed to operational &/or mechanical &/or extende drain &/or break-in (when new) reasons. Call lab if you desire to discuss.

TB2N, GREASE. WEAR METALS - gear/bearing (iron) (copper) -MILDLY ABOVE NORM (ACCEPTABLE).

TB1S, TB4S, TB5N, TB6N, TB6S, GREASE. WEAR METALS - gear/bearing (iron) (copper) -moderately high (abnormal).

TB5S, GREASE. WEAR METALS - gear/bearing (iron) (copper) -moderately high (abnormal). .

TB2S, TB3S, TB7S, GREASE. WEAR METALS - gear/bearing (iron) (copper) -high (abnormal).

Ana-Laboratories, Inc. (A-L,I)

LAB
111 Harding Avenue
Bellmawr, N. J. 08031
(609) 931-0011
(800) 257-7896

6/8/84

MILTON C.STAFFORD P.E : ATTN: MR. MILTON STAFFORD.P.E.

TB1N, GREASE. WEAR METALS - gear/bearing (iron) (copper) -high (abnormal) .

TB3N, GREASE. WEAR METALS - gear/bearing (iron) (copper) (aluminum) -high (abnormal).

TB4N, GREASE. WEAR METALS - gear/bearing (iron) (copper) (aluminum) -high (abnormal) .

SSPANLO, GEAR OIL. WEAR METALS - gear/bearing (iron) Lead wear may be from bearing ,bushing or shims/spacer,etc. -MILDLY ABOVE NORM (ACCEPTABLE). . LUBE CONTAM.- Combined contaminants (various TYPES)- -ACCEPTABLE. . Continue scheduled maint. program. Resample per your schedule. Oil drain may be extended.

UNITS SHOWING MINOR WEAR:

None.

THE REMAINING UNITS ARE SATISFACTORY OR STEADY.

RESPECTFULLY SUBMITTED.

SADIQ ALI
PRODUCT/PERFORMANCE EVALUATOR

IMPORTANT • HOW TO INTERPRET TEST DATA • READ CAREFULLY

Our test data is divided into six conditions as shown below. The respective corrective action is also indicated. The condition is determined by comparing test data against general trend/trend of similar fleets/trend of the same fleet and trend of the same unit from test to test.

THE SIX CONDITIONS ARE AS FOLLOWS:
(Please note our wider range of conditions)

	CONDITION INDEX	CORRECTIVE ACTION
6	**EXCESSIVE/UNACCEPTABLE** Critical	Must take corrective action before further use. Contact lab to discuss. Resample immediately recheck to confirm seriousness of condition.
5	**HIGH/UNACCEPTABLE** Abnormal and/ or Critical	Monitor closely or take corrective action. Immediate or half interval sampling as requested to monitor seriousness of condition.
4	**MODERATELY HIGH** Abnormal/Unacceptable	Monitor closely or take corrective action. Send half interval recheck to monitor rate of increase and determine seriousness of abnormality.
3	**MILD/ACCEPTABLE**	Monitor by sending recheck sample as requested so that the rate of increase may be monitored for its seriousness.
2	**MODERATE** Normal/Acceptable	Lab will monitor. Follow normal operation and sampling. The sample shows minor trend change since last report.
1	**SATISFACTORY** Normal/Acceptable	Lab will monitor. Follow normal operation and sampling.

RECOMMENDATIONS are divided into: a. Conditions of the wear metals and their severity; b. Conditions of various lube contaminants and their severity; c. Corrective action advised. Each time a sample is received it is recorded on its own report card and a diagnostic interpretation of test data is given. Because of limited space all the severe findings are reported first. **THE UNMENTIONED VALUES SHOULD BE CONSIDERED SATISFACTORY OR MILD.**

FATIGUE WEAR/SNAP OFF:	Undue stress and strain cause FATIGUE WEAR to metal parts in a lubrication system. Metal particles generated may be so large that they may not stay suspended in oil. Also, particles may not be generated due to snap off of a part (misalignment, abuse, etc. causes FATIGUE WEAR)
FRICTION WEAR:	Spectrochemical analysis (from any source) measures only floating wear metals in oil which are generated by the friction between moving parts.

All the acceptable values of Wear Metals and Lube contaminants listed below are greatly affected by the following: age of unit; design/type; hr./miles on oil & unit; operational load/driving habit; road condition; filter/oil type and their duration of change.

ACCEPTABLE LEVELS OF TYPICAL WEAR METALS SHOWN BELOW:

METALS (P.P.M.) (Number indicates parts per million (P.P.M.)		CONTRIBUTING ENGINE SYSTEM
Aluminum	0 - 15	
Copper	0 - 30	Bearings, bushings, and valve guides
Lead	0 - 20	Lead level N/A Gasoline Engine
Tin	0 - 20	
Silver	0 - 5	
Nickel	0 - 10	Valve(s) No valve if cast iron pistons
Iron	N/V	Pistons
Aluminum	0 - 25	
Chromium	0 - 20	Ring/Liner (Cylinder)
Molybedenum	0 - 15	
Iron	0 - 145	

Other metals of interest are also monitored, i.e., cadmium/manganese, etc.

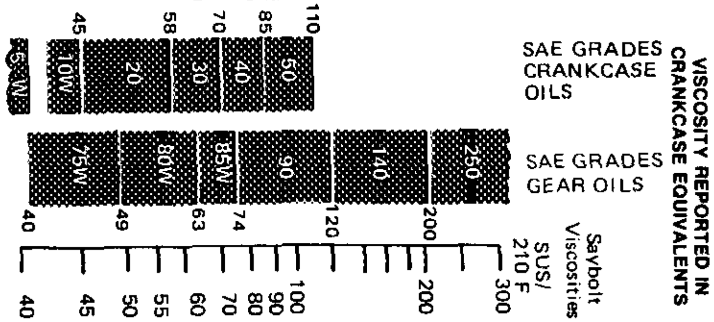
ACCEPTABLE LEVEL OF OIL CONTAMINANTS

CONTAMINANTS	LEVEL	SOURCE
Sodium (P.P.M.)	(Variable)	Oil additive, coolant, environment
Boron (P.P.M.)	(Variable)	Oil additive, coolant
Silicon (P.P.M.)	(Variable)	Oil anti-foam agent, anti-freeze
Silicon (P.P.M.)	0-25	Dust, dirt, or other abrasive
Water % by Vol.	0.1%	
Solids (Carbon, Soot, etc.)	0-5%/Vol.	Blowby product
Fuel % by Vol.	0-2	Leak

Free acid and additive packages are satisfactory when unreported. TAN, TBN are reported when requested by the customer.

Lubricity: Measure of crank case deposit and depletion of detergents i.e. Gum/Varnish/Oxidation Product.

Lubricity Codes: N/S = Normal; F/A = Acceptable; P = Poor
B = Critical



NOTE: Summary letter report is provided only when four or more samples are received at one time.

COMMENT — You must contact the lab when your findings fail to agree with the lab reports. Oil analysis results are 85% of the story. In all cases cooperation of the laboratory and the customer is important for proper interpretation of data. Services are advisory only. Liability limited to the cost of analysis. **Additive reading is quantitative.

ANA-LAB PERSONNEL EXPERIENCE EXCEEDS SEVERAL MILLION OIL ANALYSES. THIS INCLUDES ALL TYPES OF MECHANICAL LUBRICATED SYSTEMS, INCLUDING THE U.S. NAVY SUBMARINES AND U.S. COAST GUARD SQUADRONS. THUS OUR OUTPUT IS MORE IN DETAIL THAN SEEN ELSEWHERE IN THE MARKET PLACE.

Additional information is available upon request.

Ana Laboratories, Inc. (A L, I)

111 Harding Avenue • Bellmawr, New Jersey 08031 • (609) 931-0011
Toll Free (800) 257-7896 (except NEW JERSEY)

MILTON C.STAFFORD P.E
39 UNION AVENUE
BALA, CYNWYD, PA. 19004

* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* YOUR COMPUTER NAME MILSTA
* YOUR COMPUTER UNIT I.D. NRAILLO
* Type GEAR OIL
* Make N. RAIL LOCK
* Model
* Sump capacity
* Type of operation
Oil type:
* Add pkg: **

Molybdenum	Magnesium	Calcium	Barium	Phosphorus	Zinc
15			35	32	1

* Full flow filter
* Bypass filter
* Test type:
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5612	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

*IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY.

	WEAR ELEMENTS (P.P.M.)									OIL CONTAMINANTS									
	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	[illegible]	VIS(SUS)@ (100F or) 210F	Free Acid No.
EST DATA 1.	3	<1	44	27	2	2	2	162	2	4	<1	<1	<.05	0.10	A		[illegible]	45W	
EST DATA 2.																			
EST DATA 3.																			
EST DATA 4.																			
EST DATA 5.																			

WEAR METALS - gear/bearing (iron) -MILDLY ABOVE NORM (ACCEPTABLE). . LUBE CONTAM.- Combined contaminants (various TYPES)- -ACCEPTABLE. [illegible] scheduled maint. program. Resample per your schedule. Oil drain may be extended.

COMMENTS

1-THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking- silicon gasket sealer, silicon type additive, etc
2-LEAD- As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3-ANALYSIS FAILS—See reverse side (Fatigue Wear).
4-Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5-No recommendation possible due to insufficient information. Call lab if necessary.
6-Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7-Check for metal chips in oil. Call lab to discuss.
8-Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9-The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10-Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11-Check for dirt/salt breathed in or splashed in from road.
12 Check for soap, detergent splashed in during cleaning, etc.

Ana Laboratories, Inc. (A L, I)

111 Harding Avenue • Bellmawr, New Jersey 08031 • (609) 931-0011
Toll Free (800) 257-7896 (except NEW JERSEY)

MILTON C.STAFFORD P.E
39 UNION AVENUE
BALA, CYNWYD, PA. 19004

* Attn: MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* YOUR COMPUTER NAME: MILSTA
* YOUR COMPUTER UNIT I.D.: SRAILLO
* Type: GEAR OIL
* Make: SO. RAIL LOCK
* Model
* Sump capacity
* Type of operation
Oil type:
* Add pkg: ** Molybdenum 22 | Magnesium | Calcium | Barium 33 | Phosphorus 137 | Zinc 28
* Full flow filter
* Bypass filter
* Test type:
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5613	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

* IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY

WEAR ELEMENTS (P.P.M.) / OIL CONTAMINANTS

	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	TAN or [illegible]	VIS(SUS)@ (100F or) 210F	Free Acid
EST DATA 1.	3	<1	67	105	2	?	2	1447	3	?	<1	<1	<.05	0.10	A		10	90W	

WEAR METALS - gear/bearing (iron) -moderately high (abnormal). . LUBE CONTAM.- Combined contaminants (various TYPES)- -ACCEPTABLE. . Advise monitoring. Since lube contaminants are normal,this wear is attributed to operational &/or mechanical &/or extende drain &/or break-in (when new) reasons. Call lab if you desire to discuss.

should change

EST DATA 2.

EST DATA 3.

EST DATA 4.

EST DATA 5.

COMMENTS

1–THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES–may have entered during sample taking–silicon gasket sealer, silicon type additive, etc.
2–LEAD. As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3–ANALYSIS FAILS–See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7–Check for metal chips in oil. Call lab to discuss.
8–Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9–The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10–Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11–Check for dirt/salt breathed in or splashed in from road
12–Check for soap, detergent splashed in during cleaning, etc.
13–[illegible] appropriate testing and recommendation

Ana Laboratories, Inc. (A L, I)

111 Harding Avenue • Bellmawr, New Jersey 08031 • (609) 931-0011
Toll Free (800) 257-7896 (except NEW JERSEY)

MILTON C.STAFFORD P.E
39 UNION AVENUE
BALA, CYNWYD, PA. 19004

* Attn: MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* **YOUR COMPUTER NAME** MILSTA
* **YOUR COMPUTER UNIT I.D.** NSPANLO
* **Type** GEAR OIL
* **Make** N. SPAN LOCK
* **Model**
* Sump capacity
* **Type of operation**
Oil type:
* Add pkg: ** Molybdenum 10 | Magnesium | Calcium | Barium | Phosphorus 9 | Zinc 6 15
* **Full flow filter**
* Bypass filter
* **Test type:**
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5610	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

• IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY

WEAR ELEMENTS (P.P.M.) / **OIL CONTAMINANTS**

	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	[illegible]	VIS(SUS) (100F or) 210F	[illegible]
TEST DATA 1.	2	<1	10	68	1	2	1	32	2	<1	<1	<1	<.05	0.10	A		[illegible]	35W	
REMARKS	Satisfactory values.																		
TEST DATA 2.																			
REMARKS																			
TEST DATA 3.																			
REMARKS																			
TEST DATA 4.																			
REMARKS																			
TEST DATA 5.																			
REMARKS																			

COMMENTS

1–THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking- silicon gasket sealer, silicon type additive, etc.
2–LEAD- As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3–ANALYSIS FAILS–See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7–Check for metal chips in oil. Call lab to discuss.
8–Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9–The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10–Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11–Check for dirt/salt breathed in or splashed in from road
12 Check for soap, detergent splashed in during cleaning, etc.
13 [illegible] instruction sheet can lead to inappropriate testing and recommendation

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* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* **YOUR COMPUTER NAME** MILSTA
* **YOUR COMPUTER UNIT I.D.** SSPANLO
* **Type** GEAR OIL
* **Make** S. SPAN LOCK
* **Model**
* Sump capacity
* **Type of operation**
Oil type:
* Add pkg: ** Molybdenum 16, Magnesium, Calcium, Barium, Phosphorus 10, Zinc 8
* **Full flow filter**
* Bypass filter
* **Test type:**
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5611	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

*** IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY**

	WEAR ELEMENTS (P.P.M.)									OIL CONTAMINANTS								
	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	[illegible]	VIS(SUS)@ (100F or) 210F	Free Acid #
TEST DATA 1.	2	<1	39	132	1	2	1	207	2	7	<1	<1	<.05	0.10	A		[illegible]	39W	

REMARKS: WEAR METALS - gear/bearing (iron) Lead wear may be from bearing ,bushing or shims/spacer,etc. -MILDLY ABOVE NORM (ACCEPTABLE). . LUBE [illegible] Combined contaminants (various TYPES)- -ACCEPTABLE. . Continue scheduled maint. program. Resample per your schedule. Oil drain may be extended.

TEST DATA 2.

REMARKS

TEST DATA 3.

REMARKS

TEST DATA 4.

REMARKS

TEST DATA 5.

REMARKS

COMMENTS

1–THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES–may have entered during sample taking: silicon gasket sealer, silicon type additive, etc.
2–LEAD–As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3–ANALYSIS FAILS–See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7–Check for metal chips in oil. Call lab to discuss.
8–Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9–The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10–Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11–Check for dirt/salt breathed in or splashed in from road.
12–Check for soap, detergent splashed in during cleaning, etc.

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* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* YOUR COMPUTER NAME MILSTA
* YOUR COMPUTER UNIT I.D. TB1N
* Type GREASE
* Make
* Model
* Sump capacity
* Type of operation
Oil type:
* Add pkg: **

	Molybdenum	Magnesium	Calcium	Barium	Phosphorus	Zinc
*	117	49	4895	127	151	251

* Full flow filter
* Bypass filter
* Test type:
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5602	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

* IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY.

	WEAR ELEMENTS (P.P.M.)									OIL CONTAMINANTS									
	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	TAN or TBN	VIS(SUS) @ (100F or) 210F	Free Acid Ph #
TEST DATA 1.	4	1	1404	494	65	65	9	1135	7	262	2	68							
TEST DATA 2.																			
TEST DATA 3.																			
TEST DATA 4.																			
TEST DATA 5.																			

REMARKS (Test Data 1): WEAR METALS - gear/bearing (iron) (copper) -high (abnormal) .

REMARKS (Test Data 2):

REMARKS (Test Data 3):

REMARKS (Test Data 4):

REMARKS (Test Data 5):

COMMENTS

1–THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking - silicon gasket sealer, silicon type additive, etc.
2–LEAD - As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution, Call lab, if needed.
3–ANALYSIS FAILS—See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7–Check for metal chips in oil. Call lab to discuss.
8–Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9–The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10–Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11–Check for dirt/salt breathed in or splashed in from road
12–Check for soap, detergent splashed in during cleaning, etc
13–[illegible] can lead to inappropriate testing and recommendation

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MILTON C.STAFFORD P.E
39 UNTON AVENUF
BALA, CYNWYD, PA. 19004

* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* YOUR COMPUTER NAME MILSTA
* YOUR COMPUTER UNIT I.D. TB2N
* Type GREASE
* Make
* Model
* Sump capacity
* Type of operation
Oil type:

Add pkg: **	Molybdenum	Magnesium	Calcium	Barium	Phosphorus	Zinc
*	89	14	3829	108	133	117

* Full flow filter
* Bypass filter
* Test type:
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5603	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

*IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY.

WEAR ELEMENTS (P.P.M.) / OIL CONTAMINANTS

	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	TAN	VIS(SUS)@ (100F or) 210F	Free Acid Ph #
TEST DATA 1.	4	<1	707	104	30	41	5	590	4	81	1	53					2.7		
TEST DATA 2.																			
TEST DATA 3.																			
TEST DATA 4.																			
TEST DATA 5.																			

WEAR METALS - gear/bearing (iron) (copper) -MILDLY ABOVE NORM (ACCEPTABLE).

COMMENTS

1–THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking, silicon gasket sealer, silicon type additive, etc.
2–LEAD–As wear metal lead is from bearing, bushing. As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3–ANALYSIS FAILS–See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7–Check for metal chips in oil. Call lab to discuss.
8–Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9–The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10–Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11–Check for dirt/salt breathed in or splashed in from road.
12–Check for soap, detergent splashed in during cleaning, etc.
13–... sheet can lead to inappropriate testing and recommendation.

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39 UNTON AVENUE
BALA, CYNWYD, PA. 19004

* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* **YOUR COMPUTER NAME** MILSTA
* **YOUR COMPUTER UNIT I.D.** TB3N
* **Type** GREASE
* Make
* Model
* Sump capacity
* ***Type of operation***
Oil type:
* Add pkg: **

Molybdenum	Magnesium	Calcium	Barium	Phosphorus	Zinc
144	89	5289	146	171	568

* Full flow filter
* Bypass filter
* **Test type:**
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5604	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

*** IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY**

	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	TAN	VIS(SUS)@ (100F or) 210F	Free Acid pH *
	WEAR ELEMENTS (P.P.M.)									**OIL CONTAMINANTS**									
TEST DATA 1	4	1	2163	836	60	137	12	1721	13	1076	1	95							
TEST DATA 2																			
TEST DATA 3																			
TEST DATA 4																			
TEST DATA 5																			

REMARKS (Test Data 1): WEAR METALS - gear/bearing (iron) (copper) (aluminum) -high (abnormal).

REMARKS
REMARKS
REMARKS
REMARKS

COMMENTS

1-THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking—silicon gasket sealer, silicon type additive, etc.
2-LEAD As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3-ANALYSIS FAILS--See reverse side (Fatigue Wear).
4-Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5-No recommendation possible due to insufficient information. Call lab if necessary.
6-Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7-Check for metal chips in oil. Call lab to discuss.
8-Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9-The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10-Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11-Check for dirt/salt breathed in or splashed in from road.
12 Check for soap, detergent splashed in during cleaning, etc

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* Attn: MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* **YOUR COMPUTER NAME** MILSTA
* **YOUR COMPUTER UNIT I.D.** TB4N
* **Type** GREASE
* Make
* **Model**
* Sump capacity
* **Type of operation**
* Oil type:
* Add pkg: ** Molybdenum 117 Magnesium 51 Calcium 4695 Barium 52 Phosphorus 133 Zinc 374
* **Full flow filter**
* Bypass filter
* **Test type:**

R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5605	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

*** IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY**

	WEAR ELEMENTS (P.P.M.)									OIL CONTAMINANTS								
	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	VIS(SUS)@ (100F or) 210F	
TEST DATA 1	4	<1	1489	469	48	103	8	1280	8	486	<1	67						
TEST DATA 2																		
TEST DATA 3																		
TEST DATA 4																		
TEST DATA 5																		

REMARKS (Test Data 1): WEAR METALS - gear/bearing (iron) (copper) (aluminum) -high (abnormal) .

COMMENTS

1–THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking–silicon gasket sealer, silicon type additive, etc.
2- LEAD- As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3–ANALYSIS FAILS—See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7–Check for metal chips in oil. Call lab to discuss.
8–Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
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10–Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11–Check for dirt/salt breathed in or splashed in from road
12–Check for soap, detergent splashed in during cleaning, etc.
[illegible] ... can lead to appropriate testing and recommendation.

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* Attn. MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* YOUR COMPUTER NAME: MILSTA
* YOUR COMPUTER UNIT I.D.: TB5N
* Type: GREASE
* Make
* Model
* Sump capacity
* Type of operation
Oil type:
* Add pkg: ** Molybdenum 91, Magnesium 22, Calcium 4182, Barium 113, Phosphorus 131, Zinc 85
* Full flow filter
* Bypass filter
* Test type:
R.O. — P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5606	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY

	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	TAN	VIS(SUS)@ (100F or) 210F	Free Acid
TEST DATA 1.	4	<1	855	157	33	34	4	541	4	98	1	47					1.7		
TEST DATA 2.																			
TEST DATA 3.																			
TEST DATA 4.																			
TEST DATA 5.																			

(Wear Elements (P.P.M.): Titanium through Chromium; Oil Contaminants: Sodium through Free Acid)

REMARKS 1: WEAR METALS - gear/bearing (iron) (copper) -moderately high (abnormal).

REMARKS 2:

REMARKS 3:

REMARKS 4:

REMARKS 5:

COMMENTS

1–THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking–silicon gasket sealer, silicon type additive, etc.
2–LEAD. As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3–ANALYSIS FAILS—See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7–Check for metal chips in oil. Call lab to discuss.
8–Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9–The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10–Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11–Check for dirt/salt breathed in or splashed in from road.
12–Check for soap, detergent splashed in during cleaning, etc.

Ana Laboratories, Inc. (A L, I)

111 Harding Avenue • Bellmawr, New Jersey 08031 • (609) 931-0011
Toll Free (800) 257-7896 (except NEW JERSEY)

MILTON C.STAFFORD P.E
39 UNTON AVENUE
BALA, CYNWYD, PA. 19004

* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* **YOUR COMPUTER NAME** MILSTA
* **YOUR COMPUTER UNIT I.D.** TB6N
* **Type** GREASE
* **Make**
* **Model**
* Sump capacity
* **Type of operation**
Oil type:
* Add pkg: **

Molybedenum	Magnesium	Calcium	Barium	Phosphorus	Zinc
110	13	3963	42	111	168

* **Full flow filter**
* Bypass filter
* **Test type:**
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5607	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

***IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY**

	WEAR ELEMENTS (P.P.M.)									OIL CONTAMINANTS									
	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	TAN or	VIS(SUS)@ (100F or) 210F	Free Acid Ph #
TEST DATA 1.	4	<1	1188	420	52	48	3	926	5	246	<1	51							
TEST DATA 2.																			
TEST DATA 3.																			
TEST DATA 4.																			
TEST DATA 5.																			

WEAR METALS - gear/bearing (iron) (copper) -moderately high (abnormal).

COMMENTS

1-THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking–silicon gasket sealer, silicon type additive, etc.
2–LEAD As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3–ANALYSIS FAILS–See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7–Check for metal chips in oil. Call lab to discuss.
8–Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9–The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10–Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11–Check for dirt/salt breathed in or splashed in from road.
12–Check for soap, detergent splashed in during cleaning, etc.
13–Insufficient information on instruction sheet can lead to inappropriate testing and recommendation

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* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* YOUR COMPUTER NAME MILSTA
* YOUR COMPUTER UNIT I.D. TB7N
* Type GREASE
* Make
* Model
* Sump capacity
* Type of operation
Oil type:
* Add pkg: ** Molybdenum 108, Magnesium 5, Calcium 3931, Barium 41, Phosphorus 46, Zinc 167
* Full flow filter
* Bypass filter
* Test type:
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5609	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

*IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY.

	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	TAN	VIS(SUS)@ (100F or) 210F	Free Acid pH
TEST DATA 1.	4	<1	1054	245	37	46	5	478	4	173	<1	43					0.3		
TEST DATA 2.																			
TEST DATA 3																			
TEST DATA 4.																			
TEST DATA 5.																			

REMARKS (Test Data 1): WEAR METALS - gear/bearing (copper) Lead wear may be from bearing ,bushing or shims/spacer,etc. -moderately high (abnormal).

COMMENTS

1–THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking– silicon gasket sealer, silicon type additive, etc.
2– LEAD. As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3–ANALYSIS FAILS–See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7–Check for metal chips in oil. Call lab to discuss.
8–Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9–The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10–Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11–Check for dirt/salt breathed in or splashed in from road.
12–Check for soap, detergent splashed in during cleaning, etc.

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* Attn. MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* YOUR COMPUTER NAME MILSTA
* YOUR COMPUTER UNIT I.D. TBRN
* Type GREASE
* Make
* Model
* Sump capacity
* Type of operation
Oil type:
* Add pkg: **

Molybdenum	Magnesium	Calcium	Barium	Phosphorus	Zinc
93	32	4125	56	82	117

* Full flow filter
* Bypass filter
* Test type:
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5608	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

* IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY

WEAR ELEMENTS (P.P.M.) / OIL CONTAMINANTS

	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	TAN	VIS(SUS)@ (100F or) 210F	Free Acid Ph #
TEST DATA 1	5	<1	975	372	32	35	4	491	4	197	<1	48					2.2		
TEST DATA 2																			
TEST DATA 3																			
TEST DATA 4																			
TEST DATA 5.																			

REMARKS (Test Data 1): WEAR METALS - gear/bearing (copper) Lead wear may be from bearing ,bushing or shims/spacer,etc. -moderately high (abnormal).

REMARKS

REMARKS

REMARKS

REMARKS

COMMENTS

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3–*ANALYSIS FAILS–See reverse side (Fatigue Wear).*
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil
7–Check for metal chips in oil. Call lab to discuss.
8–Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9 The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10 Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11 Check for dirt/salt breathed in or splashed in from road
12 Check for soap, detergent splashed in during cleaning, etc

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MILTON C.STAFFORD P.E
39 UNION AVENUE
BALA, CYNWYD, PA. 19004

* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* YOUR COMPUTER NAME MILSTA
* YOUR COMPUTER UNIT I.D. TB1S
* Type GREASE
* Make
* Model
* Sump capacity
* Type of operation
Oil type:
* Add pkg: ** Molybdenum 108, Magnesium 20, Calcium 3799, Barium 48, Phosphorus 76, Zinc 154
* Full flow filter
* Bypass filter
* Test type:
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5594	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

*IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY

	WEAR ELEMENTS (P.P.M.)									OIL CONTAMINANTS									
	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.		VIS(SUS)@ (100F or) 210F	Free Acid pH
TEST DATA 1	4	<1	1111	218	40	36	5	600	4	233	<1	52	<.05						
TEST DATA 2																			
TEST DATA 3																			
TEST DATA 4																			
TEST DATA 5																			

REMARKS 1: WEAR METALS - gear/bearing (iron) (copper) -moderately high (abnormal).

REMARKS

REMARKS

REMARKS

REMARKS

COMMENTS

1- THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking silicon gasket sealer, silicon type additive, etc.
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3- ANALYSIS FAILS—See reverse side (Fatigue Wear).
4—Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5—No recommendation possible due to insufficient information. Call lab if necessary.
6—Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7—Check for metal chips in oil. Call lab to discuss.
8—Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
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11—Check for dirt/salt breathed in or splashed in from road.
12- Check for soap, detergent splashed in during cleaning, etc

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MILTON C.STAFFORD P.E
39 UNION AVENUE
BALA, CYNWYD, PA. 19004

Attn: MR. MILTON STAFFORD,P.E.

* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

* YOUR COMPUTER NAME MILSTA
* YOUR COMPUTER UNIT I.D. TB2S
* Type GREASE
* Make
* Model
* Sump capacity
* Type of operation
Oil type:
* Add pkg: ** Molybdenum 117 Magnesium 43 Calcium 4603 Barium 110 Phosphorus 138 Zinc 210
* Full flow filter
* Bypass filter
* Test type:
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5595	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

* IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY

WEAR ELEMENTS (P.P.M.) — OIL CONTAMINANTS

	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	TAN	VIS(SUS)@ (100F or) 210F	Free Acid Ph #
EST DATA 1.	4	<1	1250	360	46	60	5	1060	8	168	1	62					3.6		
EST DATA 2.																			
EST DATA 3.																			
EST DATA 4.																			
EST DATA 5.																			

WEAR METALS - gear/bearing (iron) (copper) -high (abnormal).

COMMENTS

1--THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking--silicon gasket sealer, silicon type additive, etc.
2--LEAD. As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3--ANALYSIS FAILS—See reverse side (Fatigue Wear).
4--Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5--No recommendation possible due to insufficient information. Call lab if necessary.
6--Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7--Check for metal chips in oil. Call lab to discuss.
8--Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9--The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10--Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11--Check for dirt/salt breathed in or splashed in from road.
12--Check for soap, detergent splashed in during cleaning, etc.

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BALA, CYNWYD, PA. 19004

* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* YOUR COMPUTER NAME	MILSTA
* YOUR COMPUTER UNIT I.D.	TB35
* Type	GREASE
* Make	
* Model	
* Sump capacity	
* Type of operation	
Oil type:	
* Full flow filter	
* Bypass filter	
* Test type:	
R.O.	P.O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5596	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

* Add pkg: **	Molybdenum	Magnesium	Calcium	Barium	Phosphorus	Zinc
*	128	37	4476	66	97	386

*** IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY.**

WEAR ELEMENTS (P.P.M.) / **OIL CONTAMINANTS**

	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	TAN	VIS(SUS)@ (100F or) 210F	Free Acid Ph #
TEST DATA 1.	4	<1	1588	346	56	96	7	804	6	214	<1	66							
TEST DATA 2.																			
TEST DATA 3																			
TEST DATA 4.																			
TEST DATA 5.																			

REMARKS (Test Data 1): WEAR METALS - gear/bearing (iron) (copper) -high (abnormal).

REMARKS

REMARKS

REMARKS

REMARKS

COMMENTS

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3–ANALYSIS FAILS—See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7–Check for metal chips in oil. Call lab to discuss.
8–Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9 - The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10 - Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11–Check for dirt/salt breathed in or splashed in from road.
12–Check for soap, detergent splashed in during cleaning, etc
13– [illegible] lead to inappropriate testing and recommendation

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* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* **YOUR COMPUTER NAME** MILSTA
* **YOUR COMPUTER UNIT I.D.** TB4S
* Type GREASE
* Make
* Model
* Sump capacity
* *Type of operation*

Oil type:

* Add pkg: ** Molybdenum 118 Magnesium 13 Calcium 4215 Barium 37 Phosphorus 53 Zinc 291
* Full flow filter
* Bypass filter
* Test type:

R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5597	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

***IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY**

	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	TAN #	VIS(SUS)@ (100F or) 210F	Free Acid Ph #
EST DATA 1.	4	<1	1327	415	52	78	6	735	6	240	<1	58					8.5		
EST DATA 2.																			
EST DATA 3																			
EST DATA 4.																			
EST DATA 5.																			

Header groups: WEAR ELEMENTS (P.P.M.) — Titanium through Chromium; OIL CONTAMINANTS — Sodium through Fuel.

WEAR METALS - gear/bearing (iron) (copper) -moderately high (abnormal).

COMMENTS

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3–ANALYSIS FAILS—See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7–Check for metal chips in oil. Call lab to discuss.
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* Attn. MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

* YOUR COMPUTER NAME MILSTA
* YOUR COMPUTER UNIT I.D. TB5S
* Type GREASE
* Make
* Model
* Sump capacity
* Type of operation
Oil type:
* Add pkg: ** Molybdenum 119 Magnesium 41 Calcium 4502 Barium 67 Phosphorus 71 Zinc 164
* Full flow filter
* Bypass filter
* Test type:
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5598	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

*** IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY.**

WEAR ELEMENTS (P.P.M.) / **OIL CONTAMINANTS**

	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.		VIS(SUS) (100F or) 210F	Free Acid ph #
EST DATA 1	4	<1	1222	284	46	36	5	585	5	213	<1	51					4.5		
EST DATA 2																			
EST DATA 3																			
EST DATA 4																			
EST DATA 5																			

WEAR METALS - gear/bearing (iron) (copper) -moderately high (abnormal). .

COMMENTS

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2– LEAD– As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3–ANALYSIS FAILS–See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
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10–Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11–Check for dirt/salt breathed in or splashed in from road.
12–Check for soap, detergent splashed in during cleaning, etc.

Ana Laboratories, Inc. (A L, I)

111 Harding Avenue • Bellmawr, New Jersey 08031 • (609) 931-0011
Toll Free (800) 257-7896 (except NEW JERSEY)

MILTON C.STAFFORD P.E
39 UNION AVENUE
BALA, CYNWYD, PA. 19004

* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* YOUR COMPUTER NAME MILSTA
* YOUR COMPUTER UNIT I.D. TB6S
* Type GREASE
* Make
* Model
* Sump capacity
* Type of operation
Oil type:
* Add pkg: ** Molybdenum 114 Magnesium 51 Calcium 4575 Barium 73 Phosphorus 88 Zinc 166
* Full flow filter
* Bypass filter
* Test type:
R.O. P.O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5599	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

* IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY

	WEAR ELEMENTS (P.P.M.) Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	OIL CONTAMINANTS Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	VIS(SUS)@ (100F or) 210F	Free Acid Ph #
EST DATA 1.	4	<1	1238	312	46	42	6	532	5	186	<1	54						

REMARKS: WEAR METALS - gear/bearing (iron) (copper) -moderately high (abnormal).

EST DATA 2.
REMARKS

EST DATA 3.
REMARKS

EST DATA 4.
REMARKS

EST DATA 5.
REMARKS

COMMENTS

1-THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking- silicon gasket sealer, silicon type additive, etc.
2-LEAD- As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3-ANALYSIS FAILS—See reverse side (Fatigue Wear).
4-Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5- No recommendation possible due to insufficient information. Call lab if necessary.
6- Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7-Check for metal chips in oil. Call lab to discuss.
8-Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9- The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10- Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11-Check for dirt/salt breathed in or splashed in from road.
12 Check for soap, detergent splashed in during cleaning, etc

Ana Laboratories, Inc. (A L, I)

111 Harding Avenue • Bellmawr, New Jersey 08031 • (609) 931-0011
Toll Free (800) 257-7896 (except NEW JERSEY)

MILTON C.STAFFORD P.E
39 UNTON AVENUE
BALA, CYNWYD, PA. 19004

Attn: MR. MILTON STAFFORD,P.E.

* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

* YOUR COMPUTER NAME	MILSTA
* YOUR COMPUTER UNIT I.D.	TB7S
* Type	GREASE
* Make	
* Model	
* Sump capacity	
* Type of operation	
Oil type:	
* Full flow filter	
* Bypass filter	
* Test type:	
R.O.	P O

* Add pkg: **

Molybdenum	Magnesium	Calcium	Barium	Phosphorus	Zinc
129	40	4019	84	156	257

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5600	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

***IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY.**

	WEAR ELEMENTS (P.P.M.)									OIL CONTAMINANTS									
	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.		VIS(SUS) @ (100F or) 210F	Free Acid
EST DATA 1.	4	<1	1567	354	54	52	7	1405	6	282	1	60							
EST DATA 2.																			
EST DATA 3																			
EST DATA 4.																			
EST DATA 5.																			

WEAR METALS - gear/bearing (iron) (copper) -high (abnormal).

REMARKS

COMMENTS

1–THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking, silicon gasket sealer, silicon type additive, etc.
2–LEAD–As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution. Call lab, if needed.
3–ANALYSIS FAILS—See reverse side (Fatigue Wear).
4–Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5–No recommendation possible due to insufficient information. Call lab if necessary.
6–Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7–Check for metal chips in oil. Call lab to discuss.
8–Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9–The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10–Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11–Check for dirt/salt breathed in or splashed in from road.
12 Check for soap, detergent splashed in during cleaning, etc.
13 [illegible] sheet can lead to inappropriate testing and recommendation.

Ana Laboratories, Inc. (A L, I)
111 Harding Avenue • Bellmawr, New Jersey 08031 • (609) 931-0011
Toll Free (800) 257-7896 (except NEW JERSEY)

MILTON C.STAFFORD P.E
39 UNION AVENUE
BALA, CYNWYD, PA. 19004

* Attn MR. MILTON STAFFORD,P.E.
215/664-2741

* Copies

Attn: MR. MILTON STAFFORD,P.E.

* YOUR COMPUTER NAME MILSTA
* YOUR COMPUTER UNIT I.D. TBBS
* Type GREASE
* Make
* Model
* Sump capacity
* Type of operation
Oil type:

	Molybdenum	Magnesium	Calcium	Barium	Phosphorus	Zinc
* Add pkg: **	89	20	3717	100	125	109

* Full flow filter
* Bypass filter
* Test type:
R.O. P O

TEST NO	LAB NO	CUSTOMER SAMPLE DATED	SAMPLE REC'D PROCESSING DATE	HOURS/MILES SYSTEM (SOH)	HOURS/MILES OIL	OIL ADDED	OIL DRAINED	FILTER CHANGED
1.	D5601	0/00/ 0	6/06/84					
2.								
3.								
4.								
5.								

* IMPORTANT: NOTIFY LAB OF ANY CHANGES IN THIS CATEGORY

	Titanium	Silver	Copper	Lead	Tin	Aluminum	Nickel	Iron	Chromium	Sodium (P.P.M.)	Boron (P.P.M.)	Silicon (P.P.M.)	Water % by Vol.	Solids (Carbon Soot) % by Vol.	Lubricity Code	Fuel % by Vol.	TAN or	VIS(SUS)@ (100F or) 210F	Free Acid Ph #
	WEAR ELEMENTS (P.P.M.)									OIL CONTAMINANTS									
TEST DATA 1.	4	<1	949	121	33	31	5	239	4	137	1	46							
TEST DATA 2.																			
TEST DATA 3.																			
TEST DATA 4.																			
TEST DATA 5.																			

REMARKS (Test Data 1): WEAR METALS - gear/bearing (copper) -moderately high (abnormal).

COMMENTS

1—THIS SILICON MAY OR MAY NOT BE ABRASIVE. POSSIBLE SOURCES—may have entered during sample taking—silicon gasket sealer, silicon type additive, etc.
2—LEAD. As wear metal lead is from bearing, bushing; As contaminant it may be from gasoline, starting fluid, lead type gasket sealers, paints, etc. Its severity status can be best determined by the operator. Our recommendation for corrective action varies from customer to customer and operation to operation. Caution: Call lab, if needed.
3—ANALYSIS FAILS—See reverse side (Fatigue Wear).
4—Improved conditions may be due to low time (miles or hours) on oil/reduced load.

SEE REVERSE SIDE

CHECKS

5—No recommendation possible due to insufficient information. Call lab if necessary.
6—Very low wear metals &/or lube contaminants (solids in particular) indicate low time (miles &/or hours) on oil.
7—Check for metal chips in oil. Call lab to discuss.
8—Check for possible moisture built up in the lube due to cold operation, over idling, moisture in new lube, etc.
9—The abnormalities in this case (if any) are probably due to mechanical &/or operational reasons. Call lab to discuss.
10—Check for over idling, lugging, too rich air/fuel mix, or too long oil drain intervals.
11—Check for dirt/salt breathed in or splashed in from road
12—Check for soap, detergent splashed in during cleaning, etc

Jackson Plumbing & Heating Inc.

BOX 68 · 2 COUNTY RD. · BOURNE, MASS. 02532 · PHONE 759-2715

May 14, 1984

Milton C. Stafford
39 Union Avenue
BalaCynwyd, Pa 19004

Inspection Report May 7, 1984

1. 30 gallon electric water heater appears to be leaking at the element.

2. Pedestal lavatory is cracked and should be replaced with a regular 19x17 lavatory or a utility type sink with wrist handles.

3. 4" sewer drain line which now empties into canal is cracked its entire length and needs to be replaced.

4. It is illegal to have people working without toilet facilities under Mass. State plumbing laws. Also it is illegal to discharge into the canal.
I recommend a 1000 gallon holding tank located on the bank by the maintenance shed. When the new 4" drain line is run a new insulated water line should be run so that there would be water to the bridge control office year round. This is required by law. The present water holding tank could then be removed.

George L. Jackson

George L. Jackson

APPENDIX C

NON-DESTRUCTIVE TESTING REPORT

Arnold Greene
Testing Laboratories
~~Incorporated~~

East Natick Industrial Park
6 Huron Drive • Natick, MA 01760
(617) 235-7330, 653-5950
Telex 948459 GREENELAB NTIK

Nondestructive • Chemical • Pollution • Metallurgical
Inspection • Evaluation • Analysis
Research • Development

DIVISION OF CONAM INSPECTION

Branch Laboratories:
Springfield, Mass. 01104
(413) 734-6548

Auburn, Mass. 01501
(617) 832-5500

TO: MODJESKI & MASTERS
CONSULTING ENGINEERS
P.O. BOX 2345

HARRISBURG, PA 07105

DATE: 5/10/84

JOB NO: 48847-1

LAB NO: NATICK

ORDER NO:NONE

MATERIAL: STEEL

SPECIFICATIONS:

CUSTOMER (NO CRACKS ALLOWED)

MAGNETIC PARTICLE INSPECTION

THE FOLLOWING TRUSS AND STRINGER CONNECTIONS WERE INSPECTED AT HE BUZZARD BAY RAILROAD BRIDGE, BUZZARDS BAY MASS.

LIFT SPAN - TRUSS L3 WEST ACCEPTABLE

TRUSS L8 EAST ACCEPTABLE

STRINGER CONNECTIONS - NORTH TOWER AT PANEL POINT

L4 - ACCEPTABLE

SOUTH TOWER AT PANEL POINT

L4 NOTE: LINEAR TYPE INDICATION APPEAR TO BE METAL

BUILD-UP WITH VISUAL INSPECTION - ACCEPTABLE

EQUIPMENT: AC-DC YOKE

#1 GRAY POWDER

IN WITNESS WHEREOF, I HAVE HEREUNTO SET MY HAND THIS
10TH DAY OF MAY 1984
ARNOLD GREENE TESTING LABORATORIES
DIVISION OF CONAM INSPECTION

L. William Metcalf 01-03 SNT Level II

APPENDIX D

VIBRATION MEASUREMENTS REPORT

VIBRATION MEASUREMENTS

BUZZARDS BAY LIFT BRIDGE

Prepared for

MODJESKI & MASTERS, CONSULTING ENGINEERS

JULY 1984

Weston Geophysical
CORPORATION

Weston Geophysical

July 31, 1984
WGC - R539

Mr. Richard Little
MODJESKI & MASTERS
PO Box 2345
Harrisburg PA 17105

Dear Mr. Little:

In accordance with your authorization, vibration measurements were conducted at the Buzzards Bay Lift Bridge on June 6 & 7, 1984. We are pleased to submit our report on the results of these measurements at this site.

Very truly yours,

WESTON GEOPHYSICAL CORPORATION

Peter Hubbard
For George C. Klimkiewicz

PH:GCK/rf-0778R

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDIX FIGURES

1.0 INTRODUCTION

Vibration measurements were made on the Buzzards Bay Lift Bridge on June 6 & 7, 1984 as part of an overall inspection study coordinated by Modjeski and Masters, Consulting Engineers. The bridge vibration monitoring program described in this report is a parallel of the study performed on September 7 & 8, 1971. Results of these two studies are compared in this report.

2.0 INSTRUMENTATION & PROCEDURE

As in the 1971 study, vibration data were recorded using Sprengnether Instrument Company portable Engineering Seismographs. These instruments provide three orthogonal component [2 horizontal, 1 vertical] recordings of analog vibration waveforms by direct write on 70 mm photographic paper. Three instruments were used in the present bridge vibration monitoring study. Two of these instruments recorded displacements [inches] and the third instrument recorded velocity [in/sec]. Data recorded by the third instrument were integrated, using the simple analytic procedure given in Equation 1, to compute bridge displacements.

$$D = \int V dt \qquad [1]$$

For assumed harmonic motion, Equation 1 reduces to Equation 2:

$$D_0 = V_0 / 2\Pi f \qquad [2]$$

Where D_0 = peak displacement [in.]
V_0 = peak velocity [in./sec]
f = frequency [cps]

In a manner that parallels the 1971 study, bridge vibrations were recorded for train crossings and for cycles of raising and lowering of the lift span. Recording locations occupied during the 1971 study were re-occupied for the present monitoring study, except that no data were recorded at location L5 in the present study. These monitoring locations are shown on Figure 1.

Vibration measurements were made at Locations L3S, L9, and L3N for the crossing of a coal train on June 6, 1984 and for the crossing of a passenger train on June 7, 1984. In addition, vibration measurements were recorded for a second passenger train at location L9 on June 7, 1984. It is noted that Locations L3 and L3' of the 1971 study are referred to as Locations L3S and L3N, respectively, in this study.

Finally, vibrations induced on the North and South Towers as a result of raising and/or lowering of the lift span were recorded at locations in the towers as illustrated on Figure 1.

Vibration sensors were oriented to record vertical displacements and horizontal displacements along the span [longitudinal] and perpendicular to the span [transverse].

3.0 RESULTS

All vibration records were visually scanned to identify segments of highest amplitude vibrations. Peak displacements [measured in inches] observed over a range of frequencies were scaled from the highest amplitude segments of all records. Displacement amplitudes vs. frequency data are plotted on Figures 2→16 for the 3 components of vibration at the various recording locations. Data envelopes for the 1971 study are shown on these figures to allow a comparison between these two studies. As in the 1971 study, amplitude data illustrate maxima observed over a range of frequencies; no attempt was made to scale lower amplitude displacements which were also present on the vibration records.

3.1 Train Induced Bridge Vibrations

Vibratory bridge displacements observed for the crossing of a coal train on June 6 and two passenger trains on June 7 are plotted on Figures 2→10. Figures 2→4 illustrate the 3 components of displacement at Location 3N. Displacements at this location have peak amplitudes near .01 inches at frequencies of 1.5 to 3 Hz. in horizontal components and near .04 inches in the vertical component. Displacement at lower frequencies [i.e. less than 10 Hz.] fall within the data envelope for the 1971 study. Higher frequencies [i.e. greater than 10 Hz.] are present on all vibration records. Several peak displacement amplitudes at higher frequencies are plotted on Figures 2→4. It is noted that the presence of higher frequencies was acknowledged in the 1971 report; these higher frequency data, however, were not presented at that time.

Displacements at mid-span are plotted on Figures 5→7. Results at this mid-span location are similar in amplitude to those observed at location 3N but are significantly lower than those reported in 1971 for this location, L9. In addition, the peak value of approximately 1.0 inch displacement [2.0 inch peak to peak] at a frequency of 1 Hz., reported in 1971, seems relatively high for train induced vibrations. Values given for mid-span in the 1971 study were re-examined in this study by re-interpreting the records collected in 1971. The re-interpreted vibration amplitudes at L9 are shown on Figures A-1 to A-3 in Appendix A. The re-examined records provide results that fall below or within the lower range of displacements quoted in the 1971 study. Also, the re-examined records illustrate that displacements observed in 1971 at mid-span could have been larger than those observed during the present study. Higher displacements could be related to heavier loads or to higher speeds allowed for train crossings in 1971.

Displacements at Location L3S are plotted on Figures 8→10. Vibrations at this location are similar in amplitude and frequency distribution to those observed at Locations L9 and L3N and are consistent with those reported for this location in the 1971 study.

3.2 Tower Vibrations Induced By Lifting Span

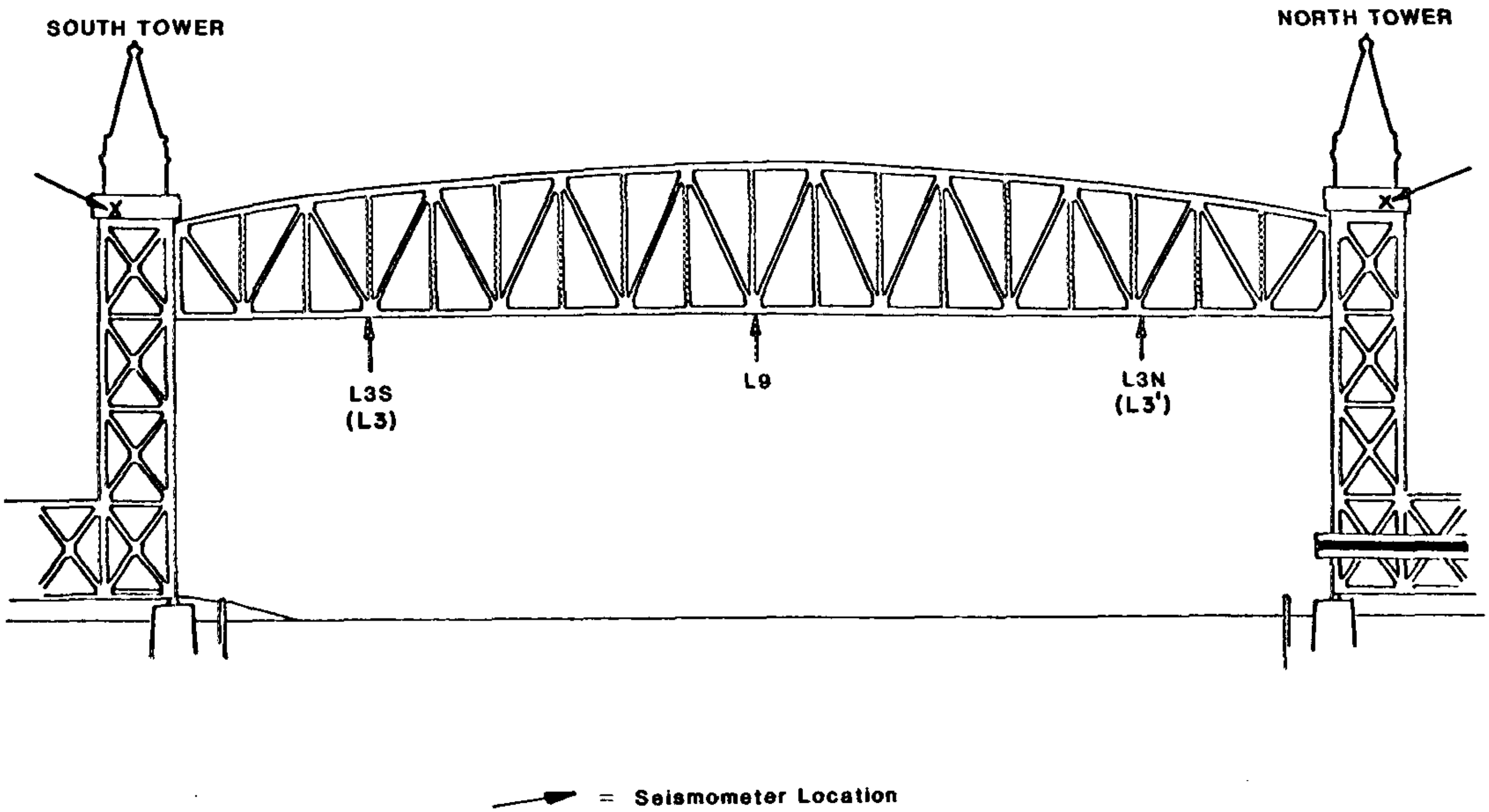
Displacements induced in the North Tower by upward and downward movement of the lift span are shown on Figures 11→13. The results of this present study are consistent with those reported in 1971.

Displacements in the South Tower for downward movement of the lift span are compared to the 1971 results on Figures 14→16. As for the case of train vibrations reported at mid-span in the 1971 study, vibrations reported in that study for the South Tower seem high. Records obtained in 1971 for the South Tower have been re-interpreted; the re-examined displacements are plotted on Figures A-4 through A-6 in Appendix A. The re-examined records provide results that fall below or within the lower range of displacements quoted in the 1971 study.

Maximum displacements observed in the towers during the present survey are approximately 0.03 inches [frequency ~0.8-1.5 Hz.] and occur in the Horizontal Components. Maximum vertical displacements observed for raising or lowering of the span are less than .01 inches. No significant variation in displacement is observed for lowering and raising of the span.

4.0 REFERENCE

Weston Geophysical Corporation, 1971, Vibration Measurements - Buzzards Bay Lift Bridge: for Parsons, Brinkeroff, Quade and Douglas, Inc., 5 p., 19 figures.



Recording Locations
FIGURE 1
Weston Geophysical

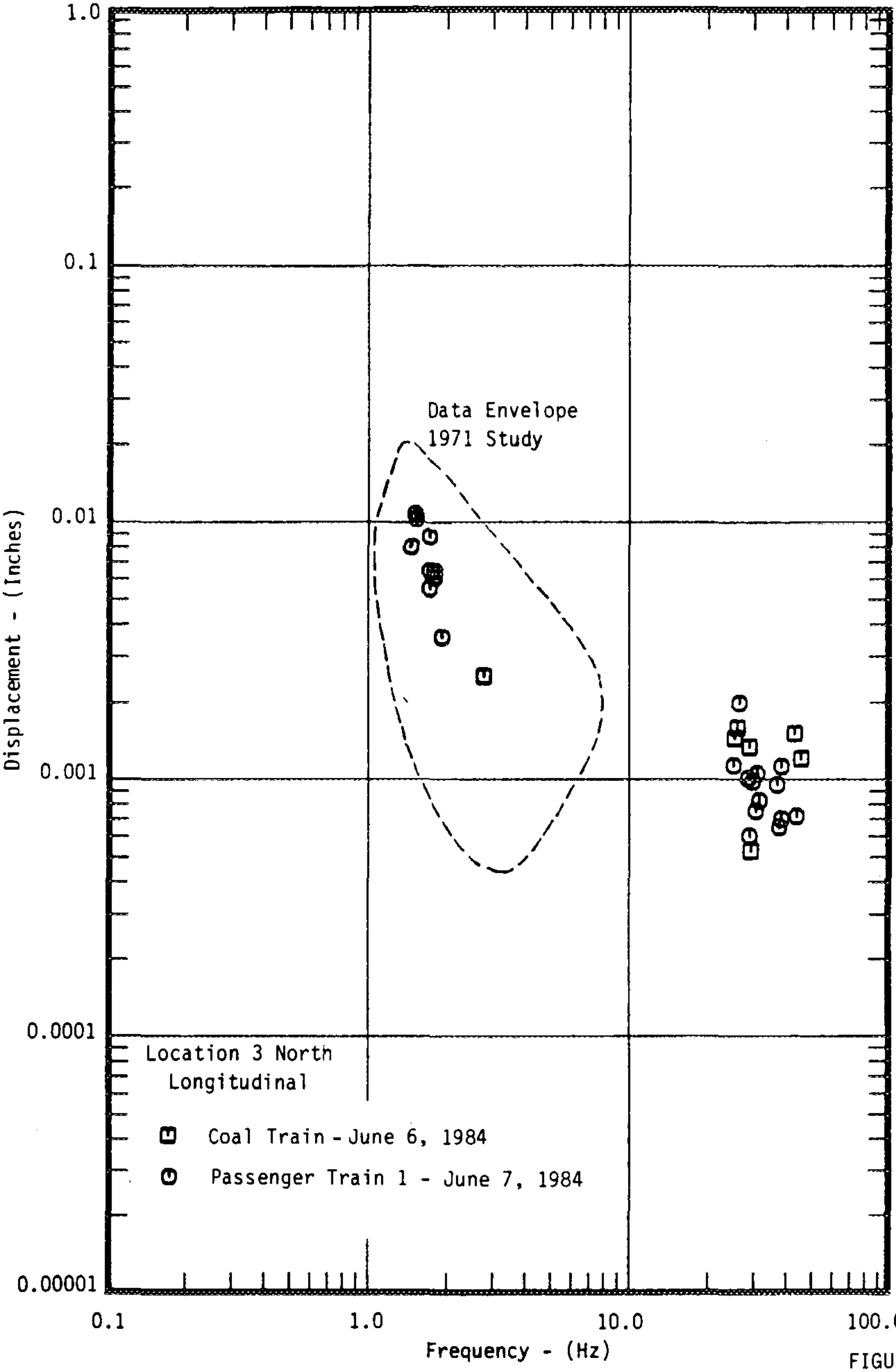


FIGURE 2
Weston Geophysical

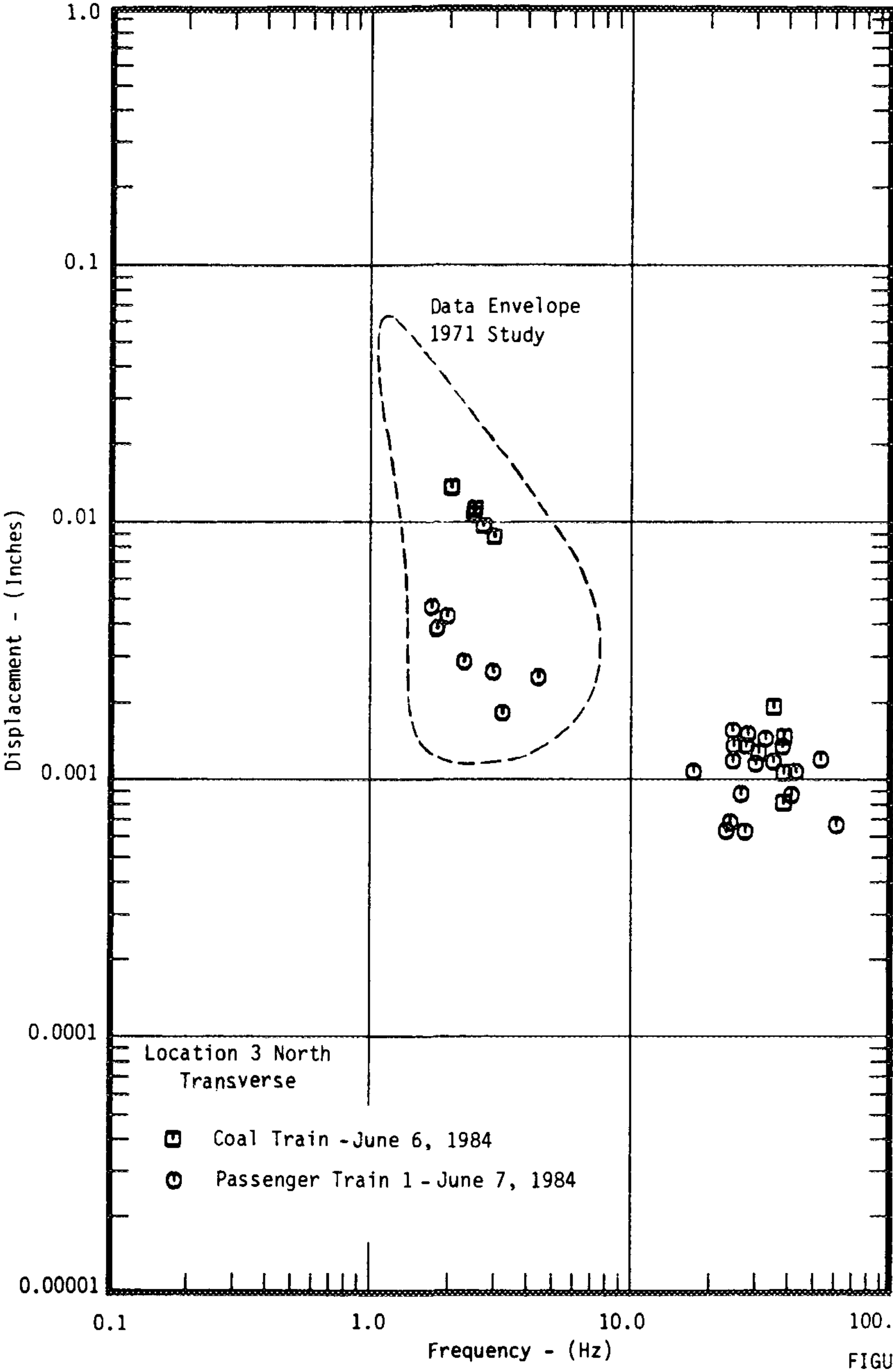


FIGURE 3
Weston Geophysical

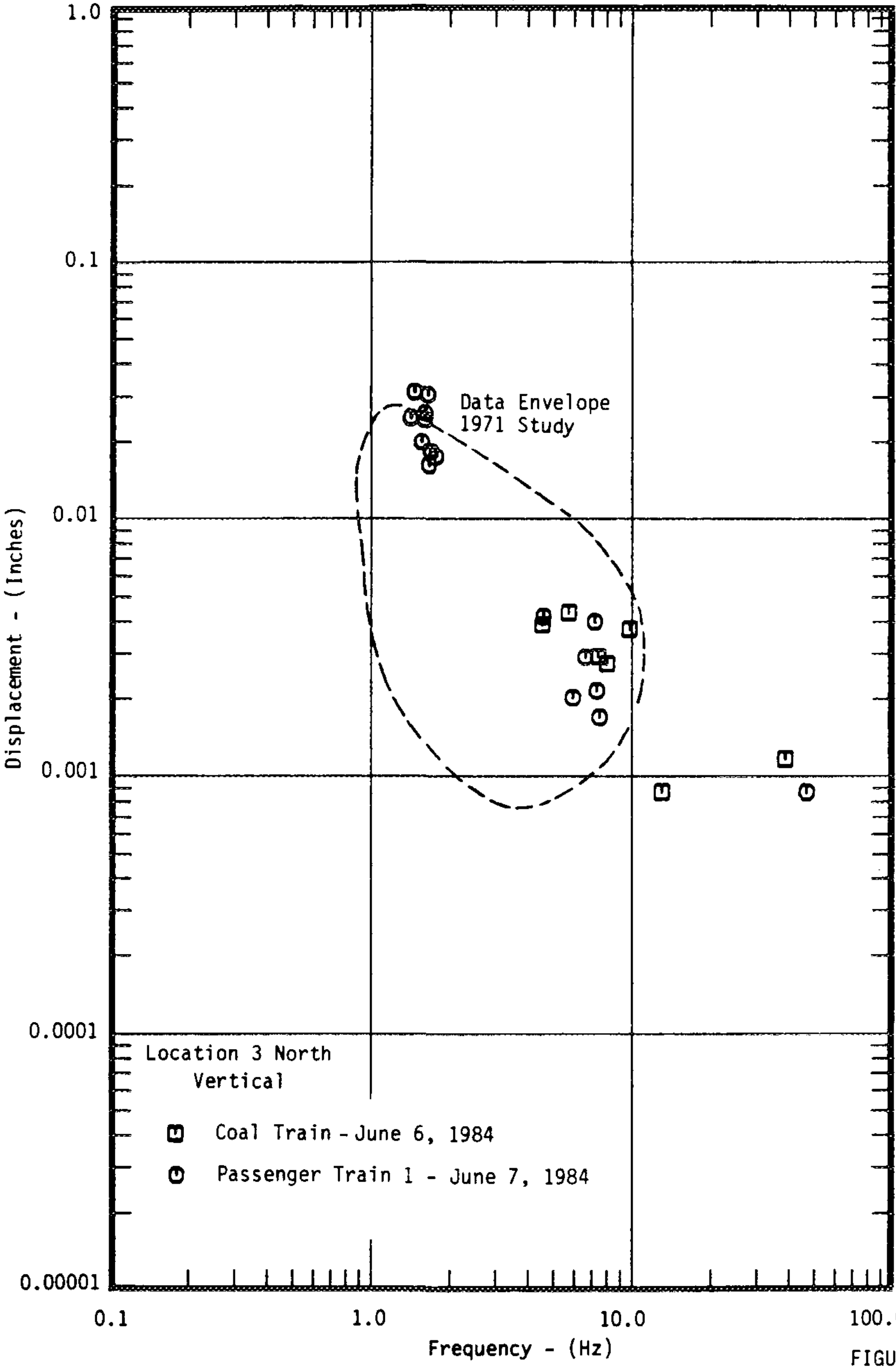


FIGURE 4
Weston Geophysical

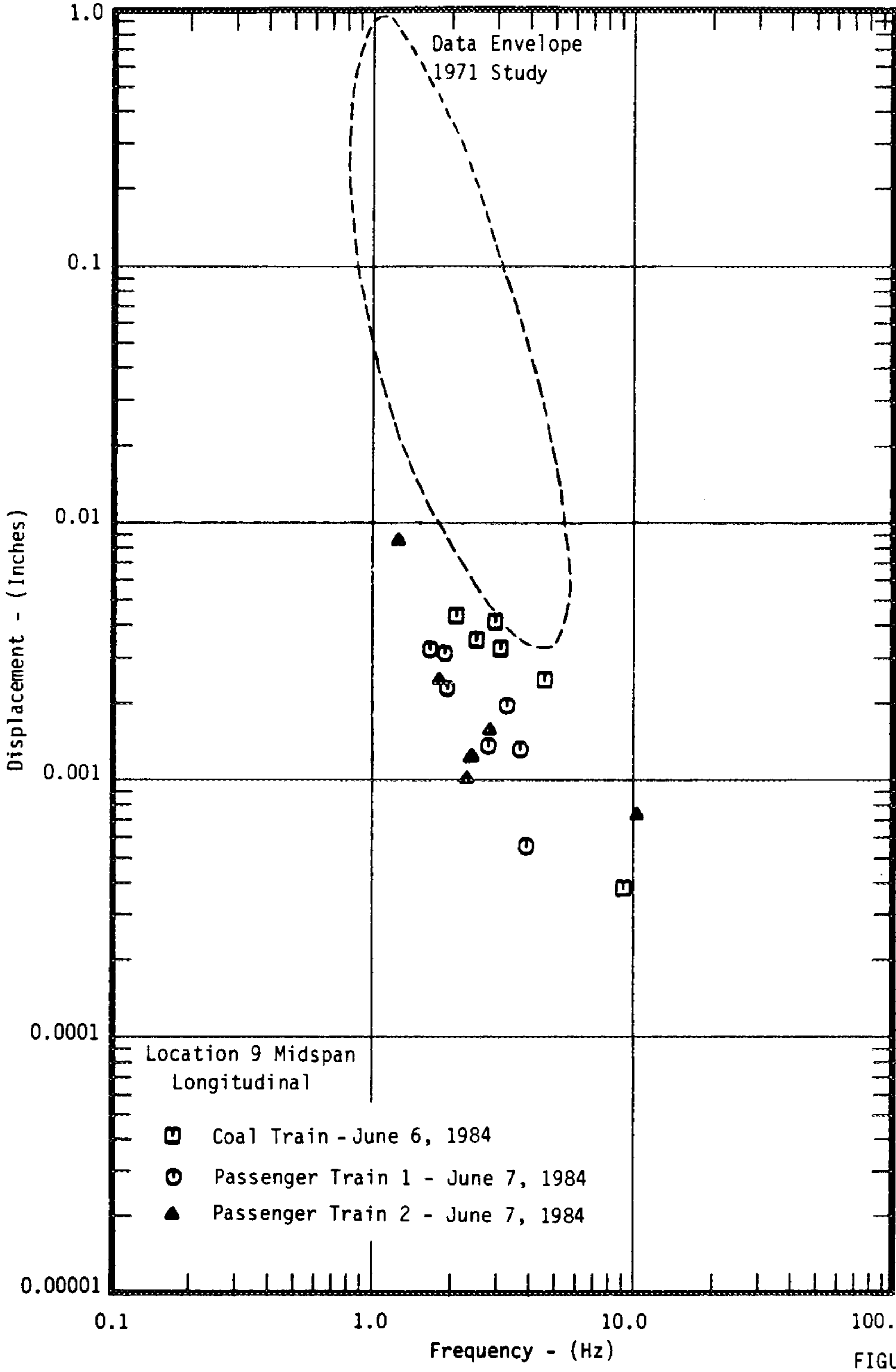


FIGURE 5
Weston Geophysical

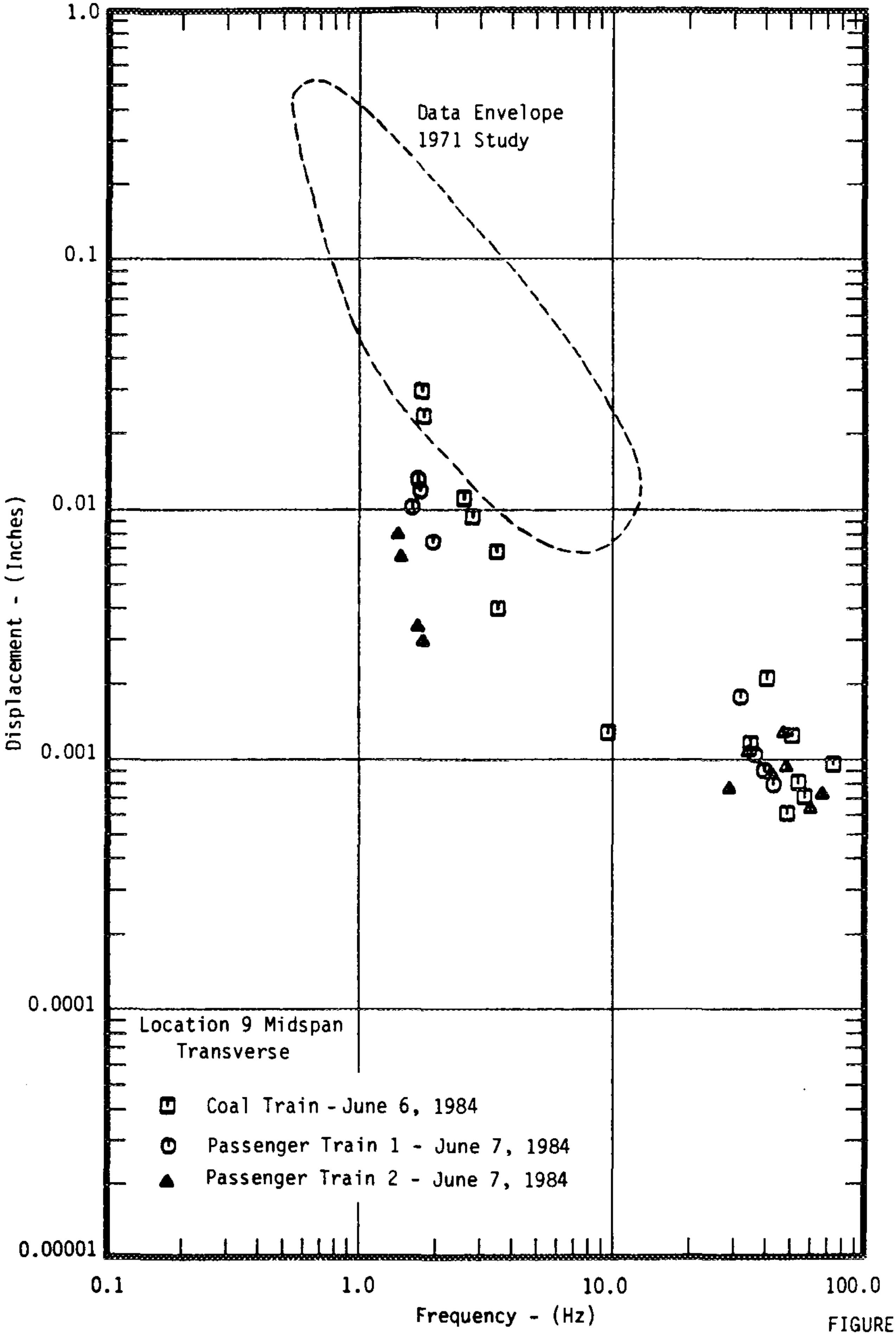


FIGURE 6
Weston Geophysical

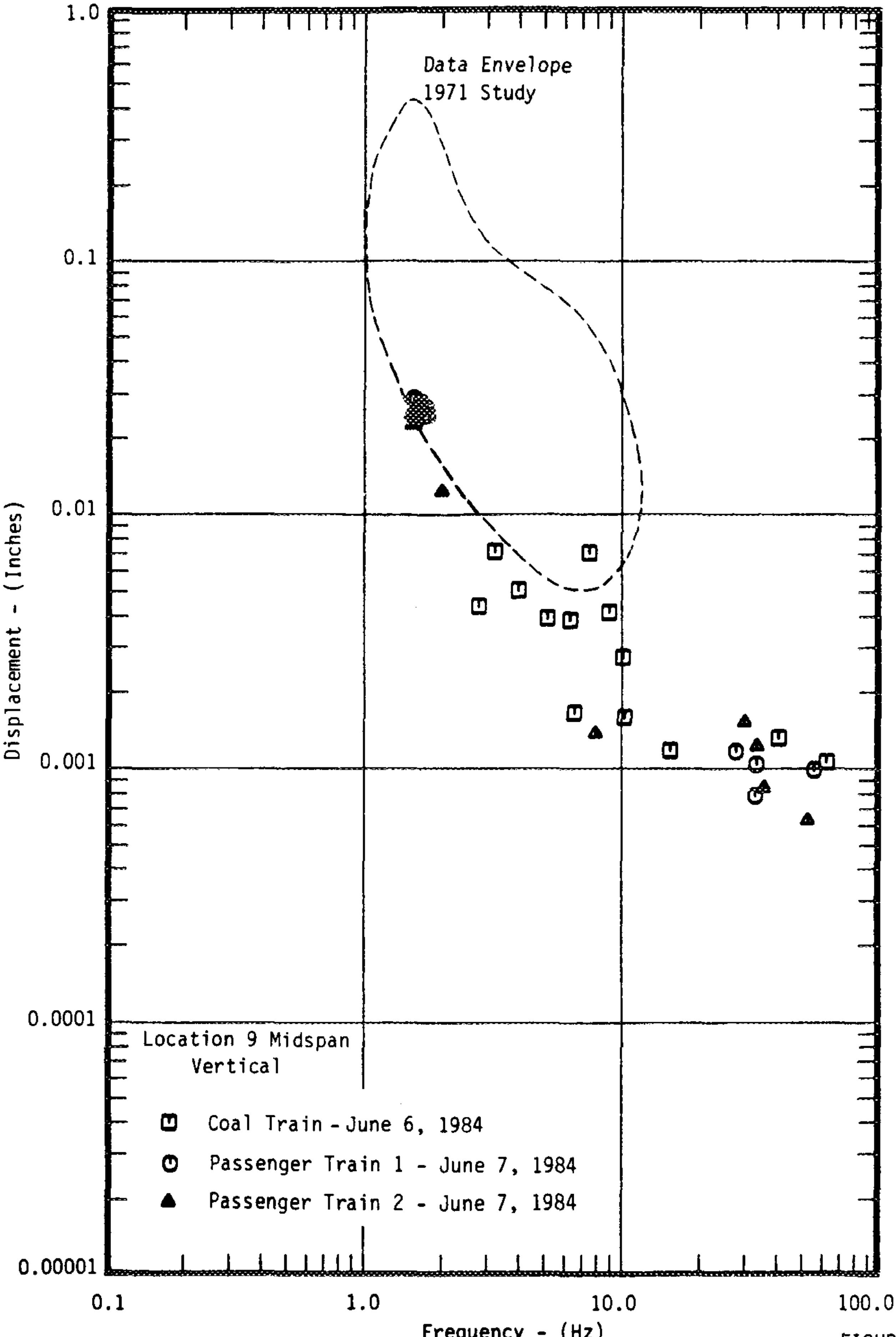


FIGURE 7
Weston Geophysical

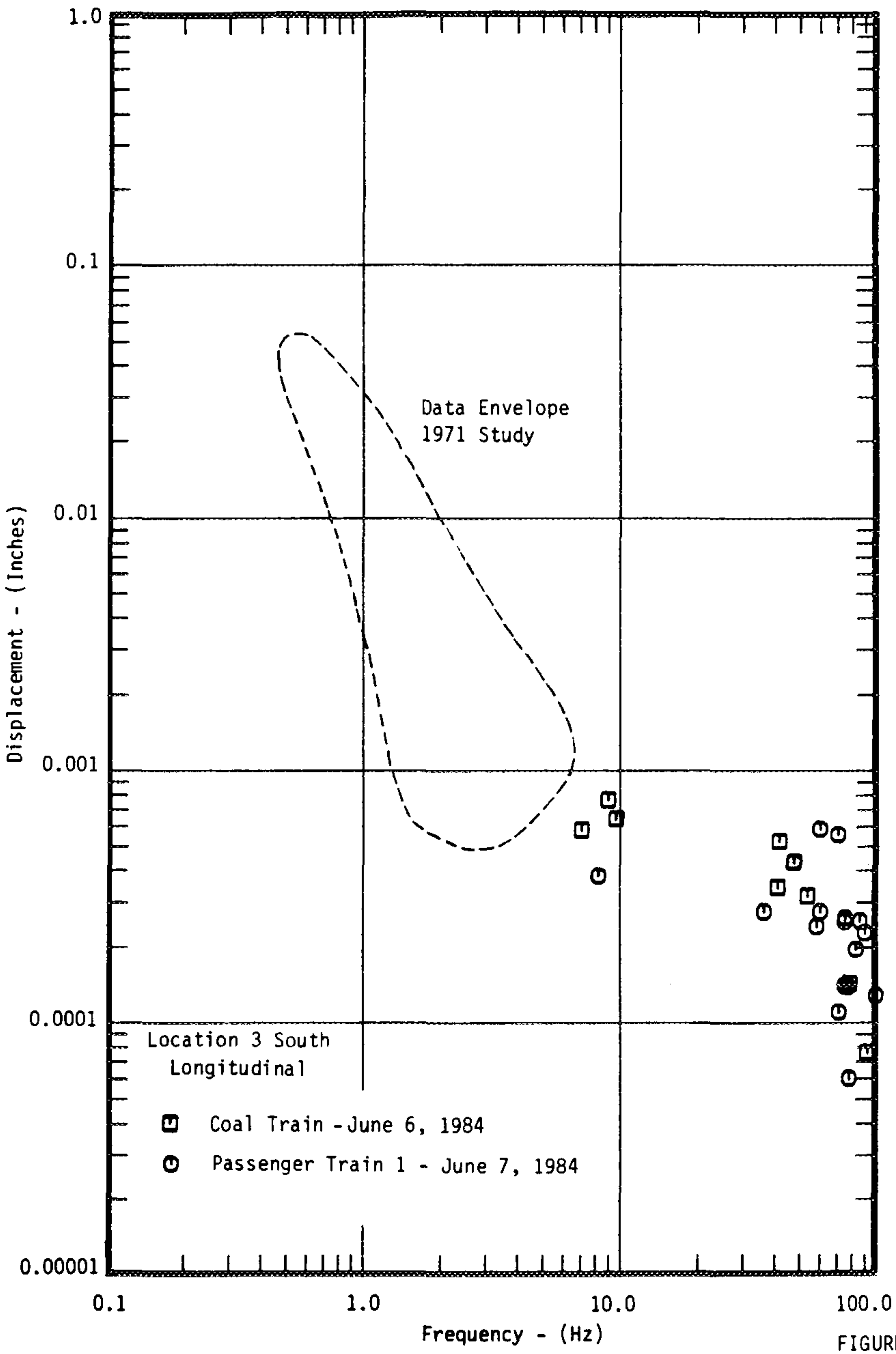


FIGURE 8
Weston Geophysical

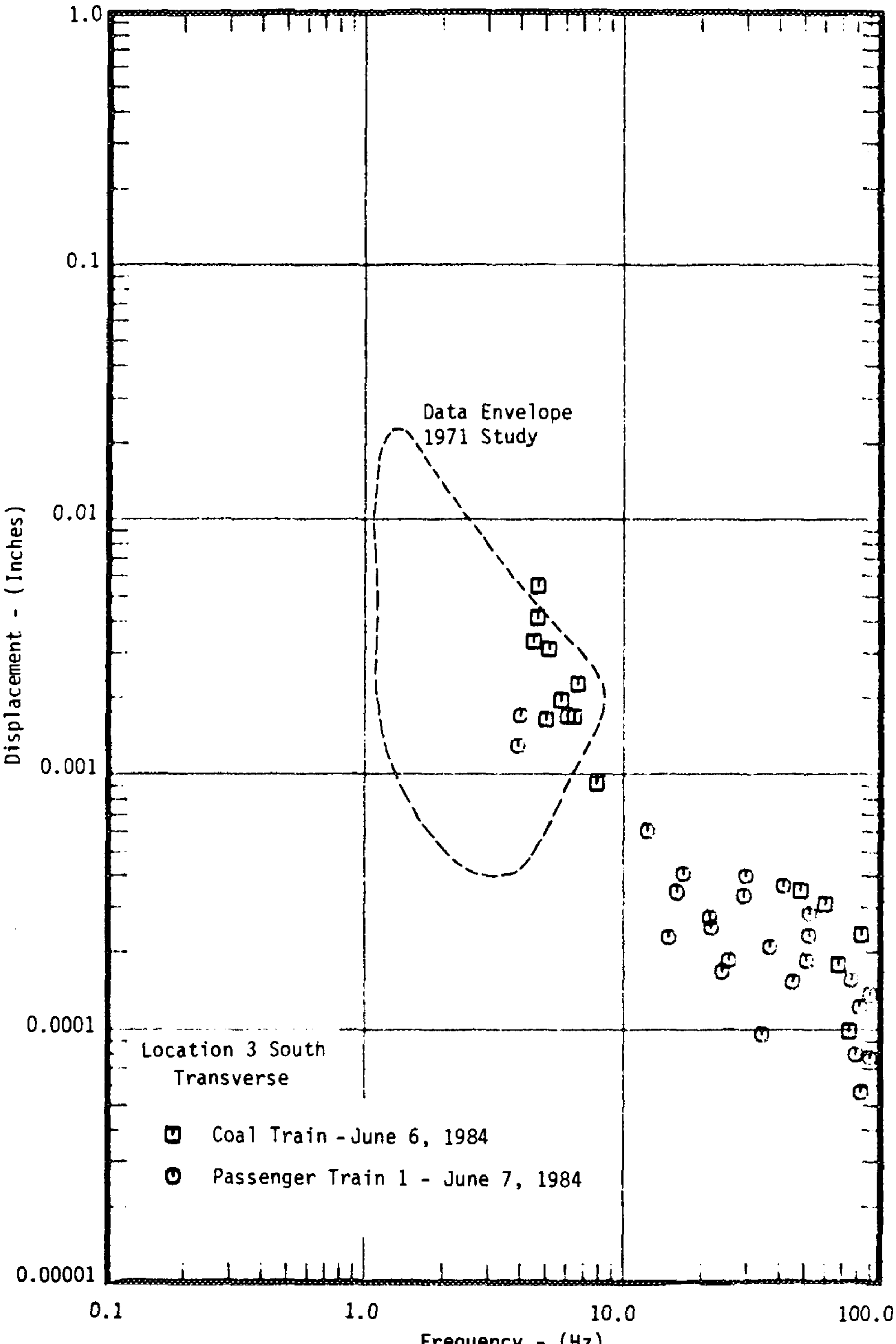


FIGURE 9
Weston Geophysical

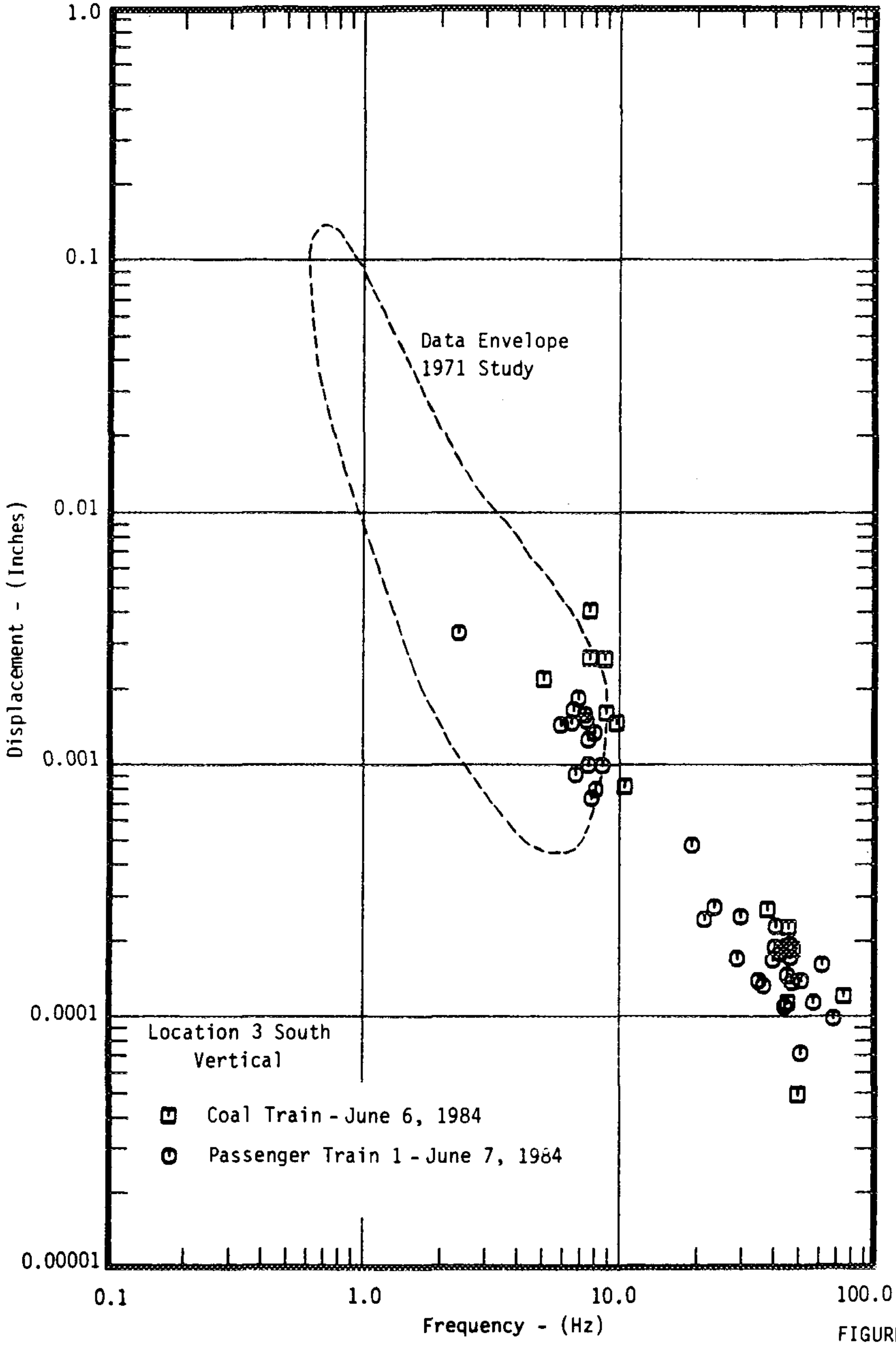


FIGURE 10
Weston Geophysical

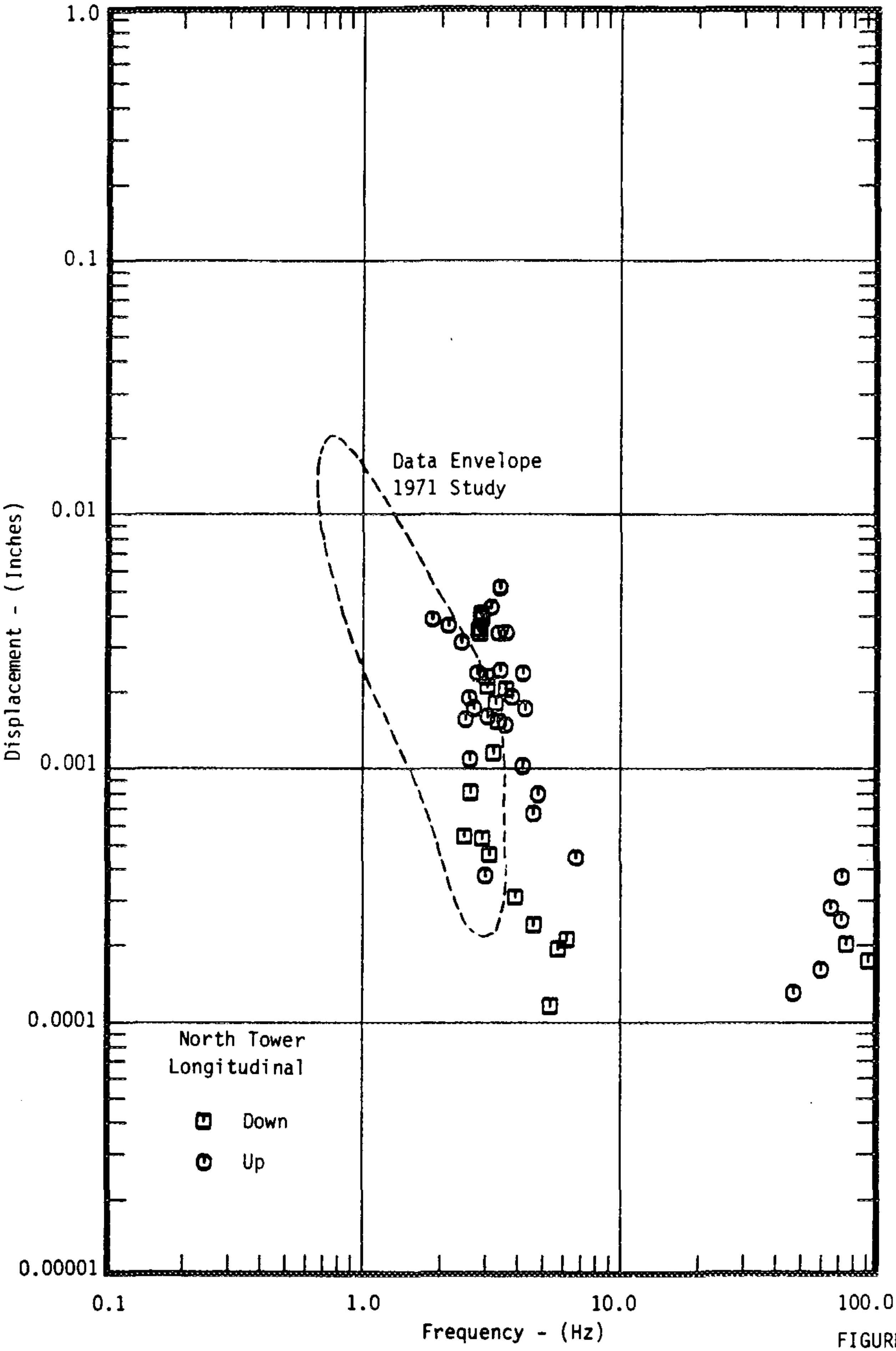


FIGURE 11
Weston Geophysical

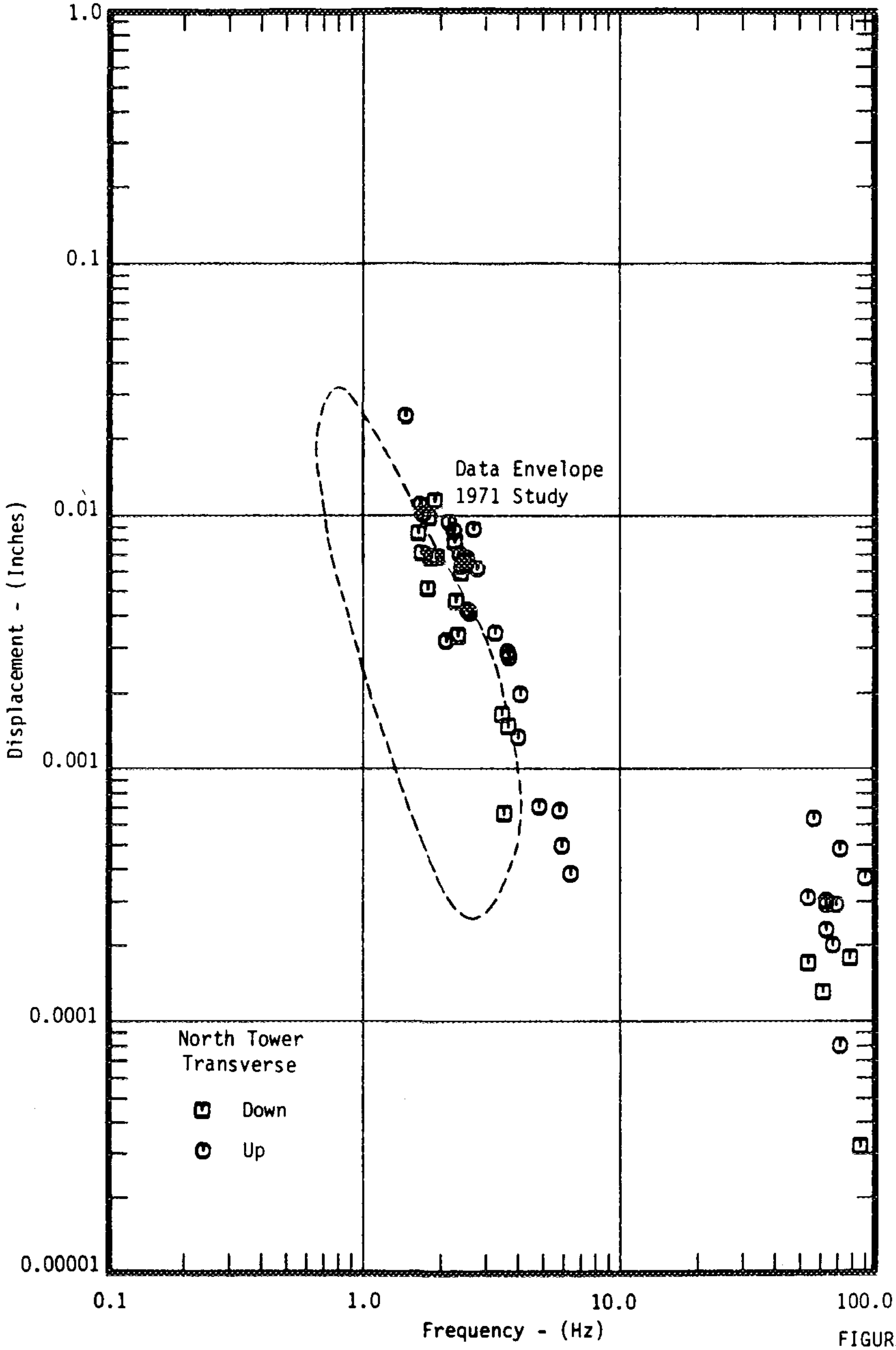


FIGURE 12
Weston Geophysical

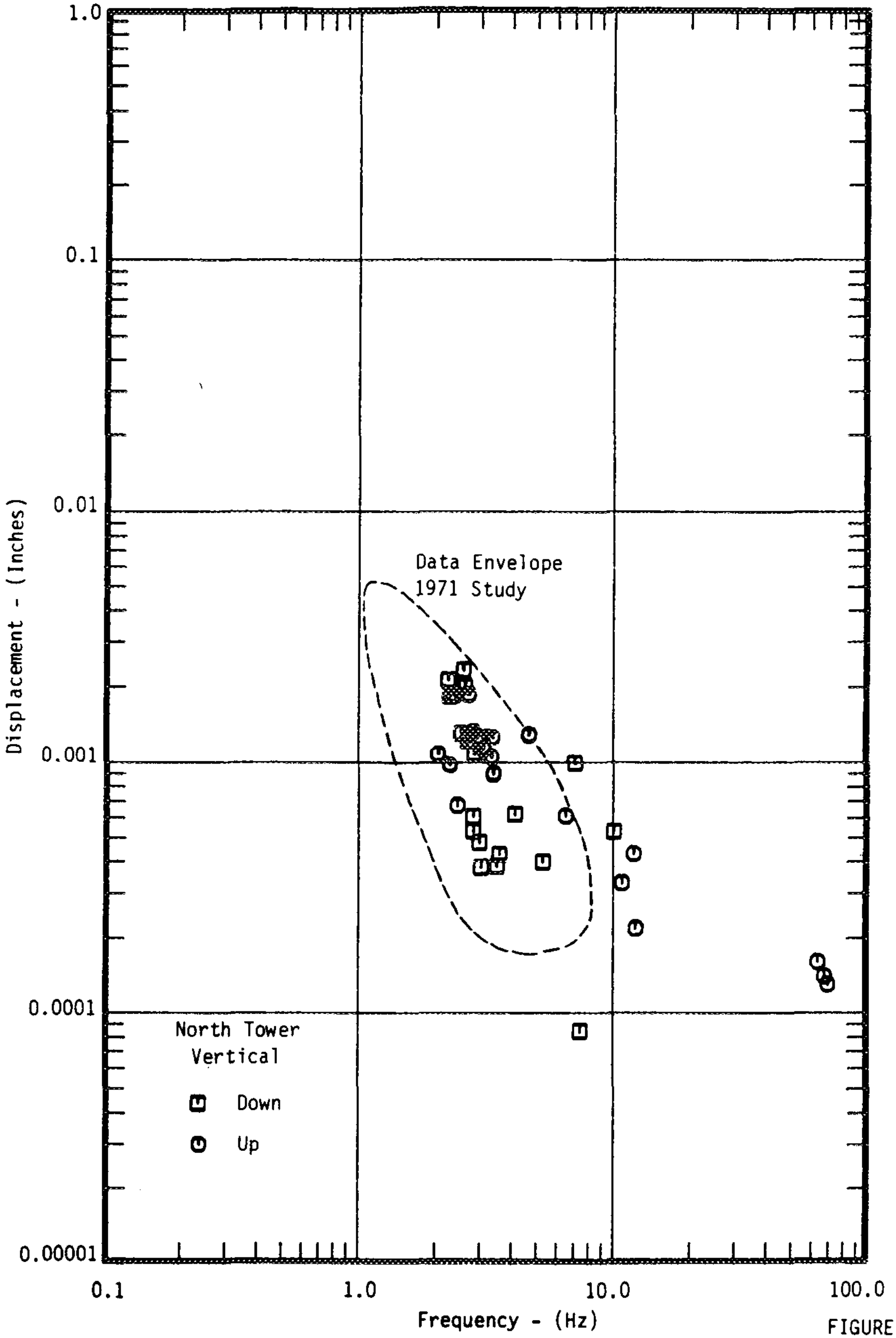


FIGURE 13
Weston Geophysical

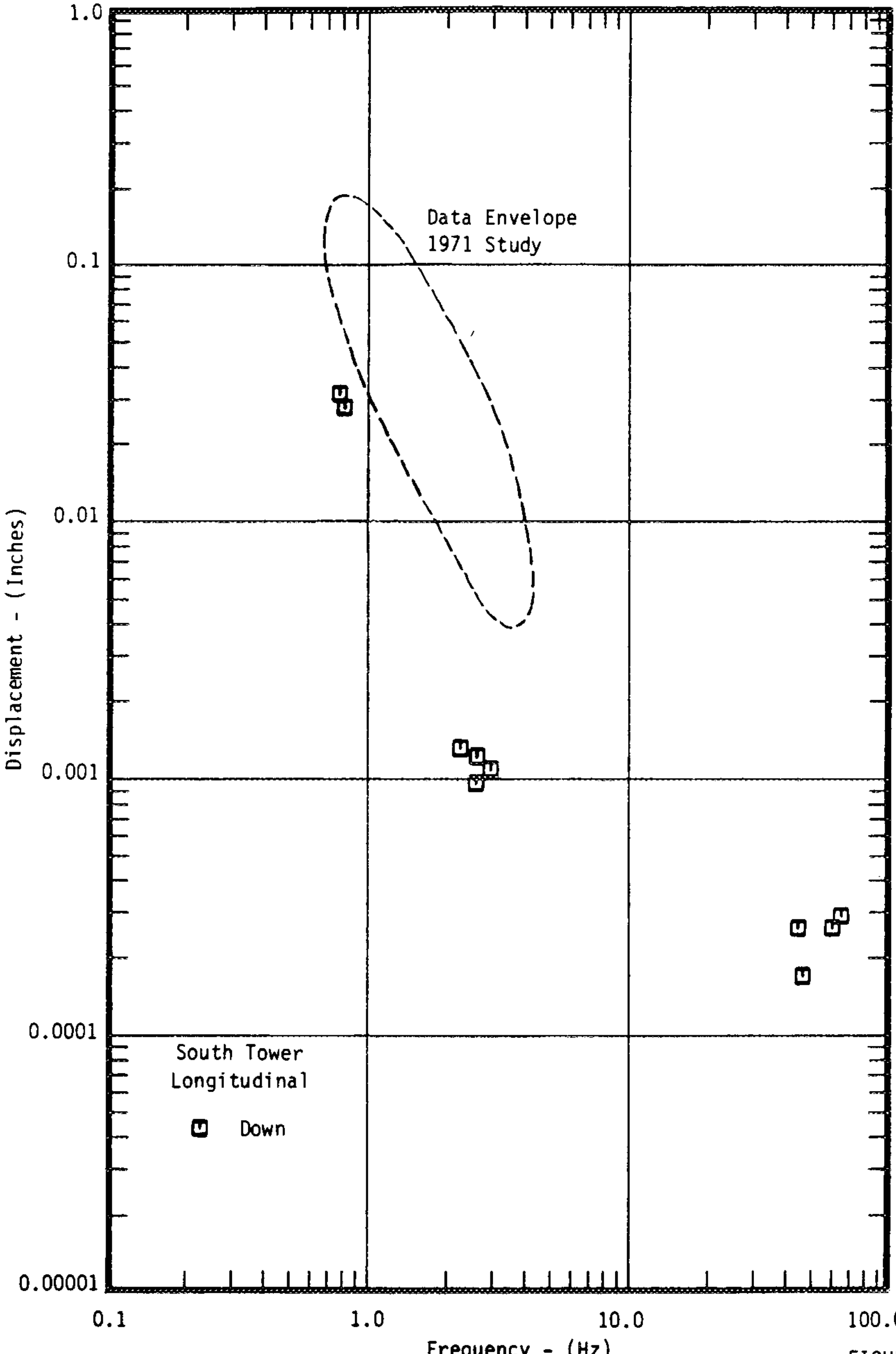


FIGURE 14
Weston Geophysical

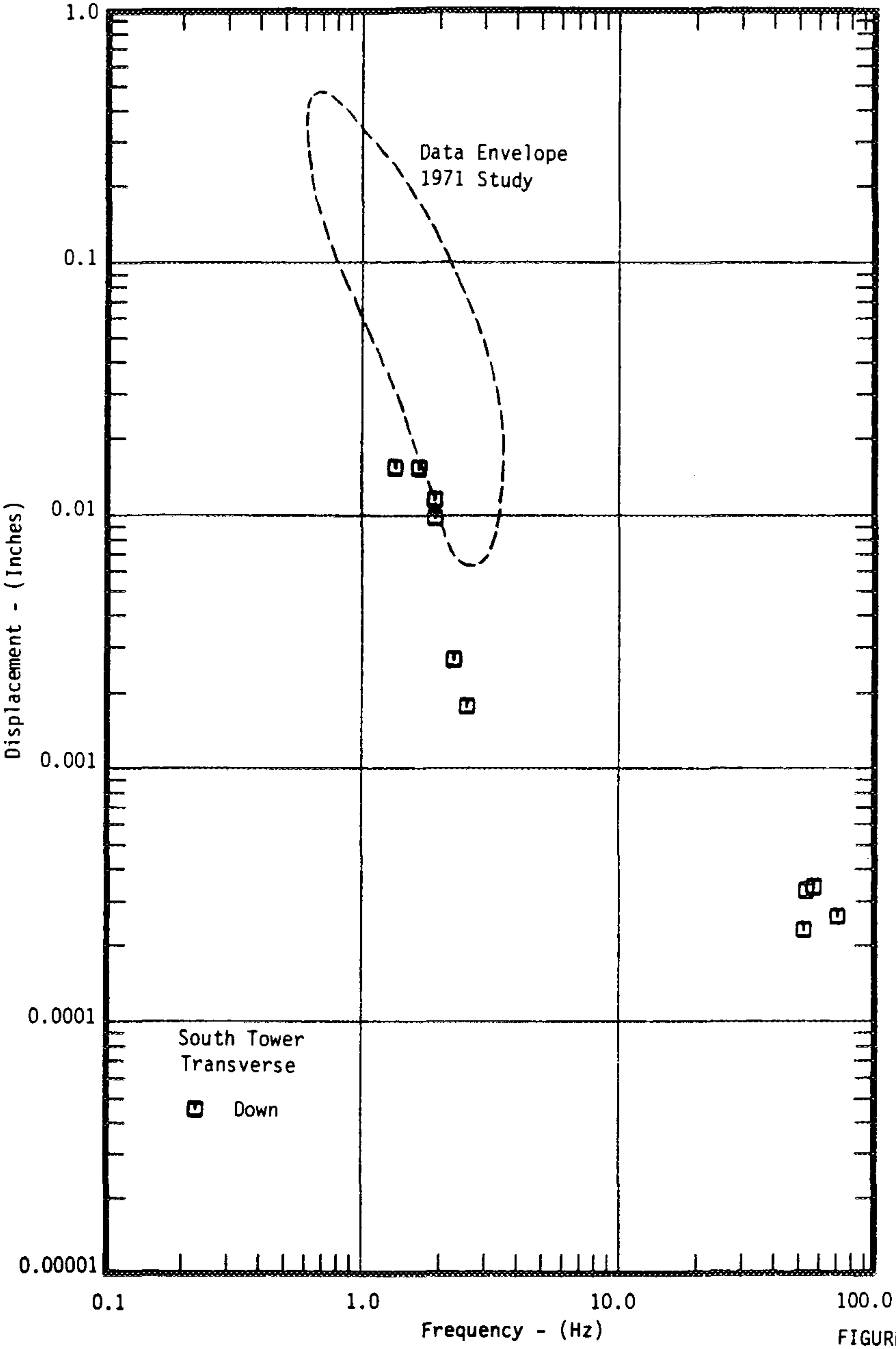


FIGURE 15
Weston Geophysical

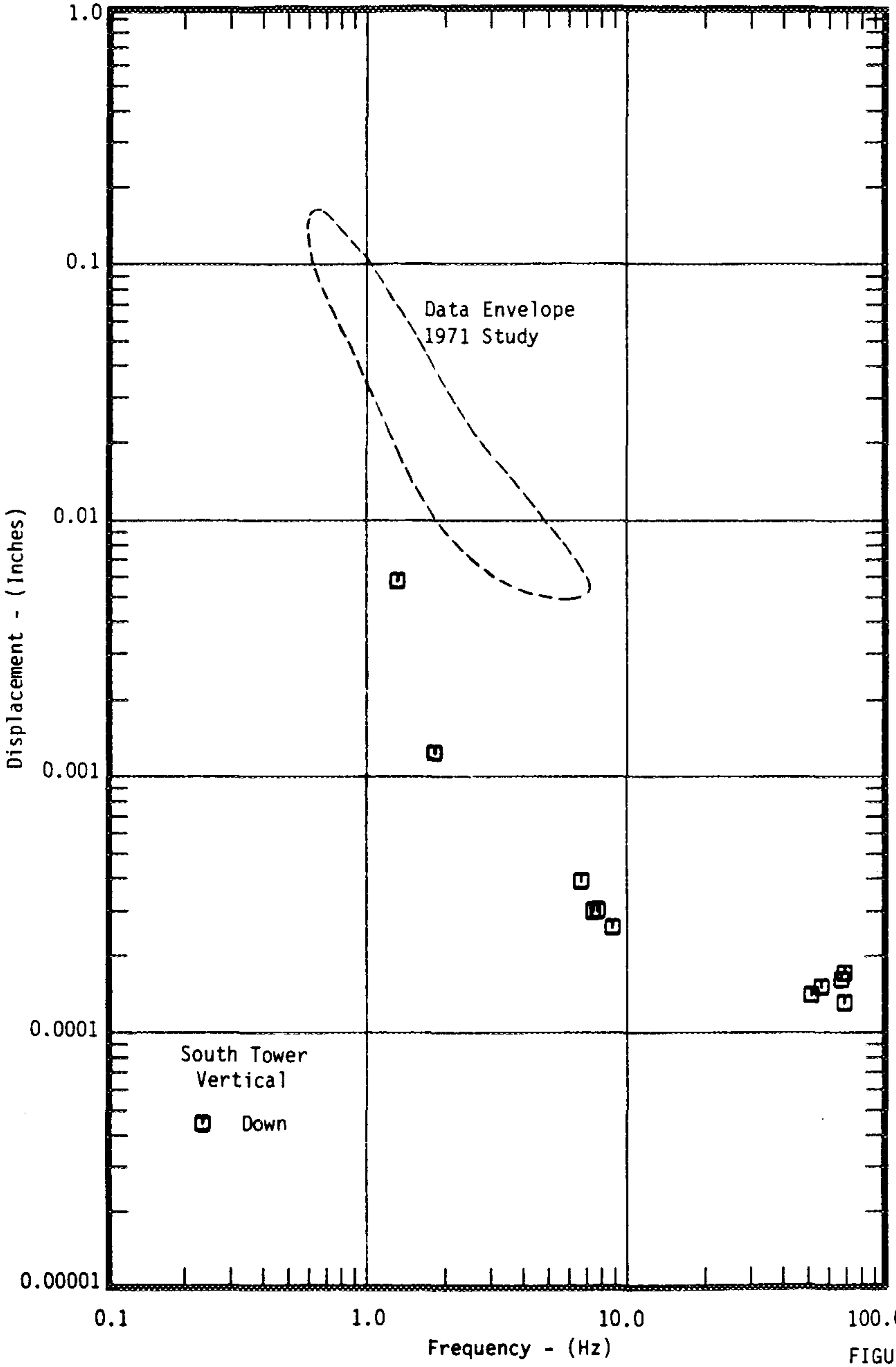


FIGURE 16
Weston Geophysical

APPENDIX A

RE-EXAMINATION OF RECORD AT MID-SPAN, 1971 STUDY
RE-EXAMINATION OF RECORD AT SOUTH TOWER, 1971 STUDY

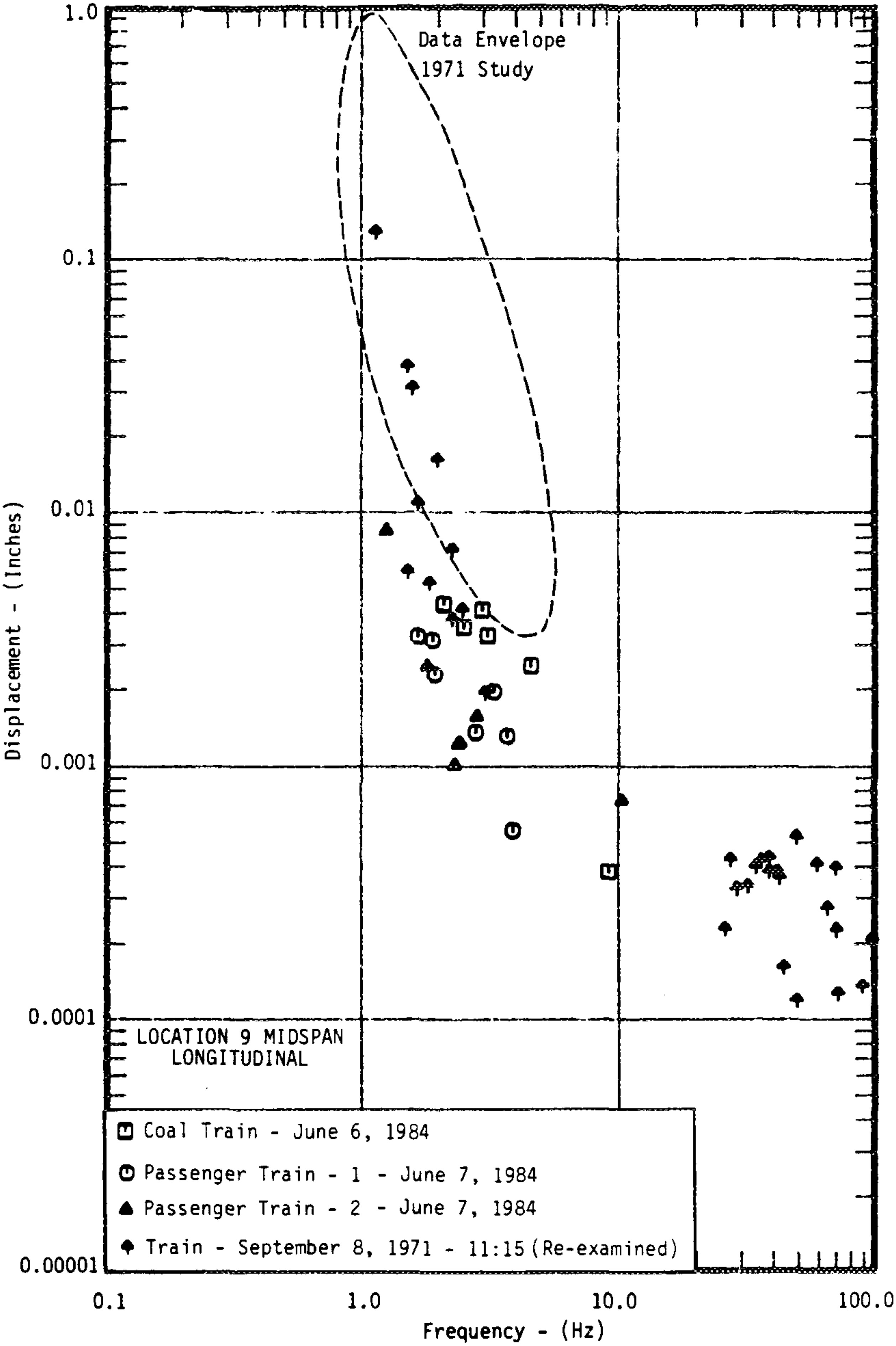


FIGURE A-1
Weston Geophysical

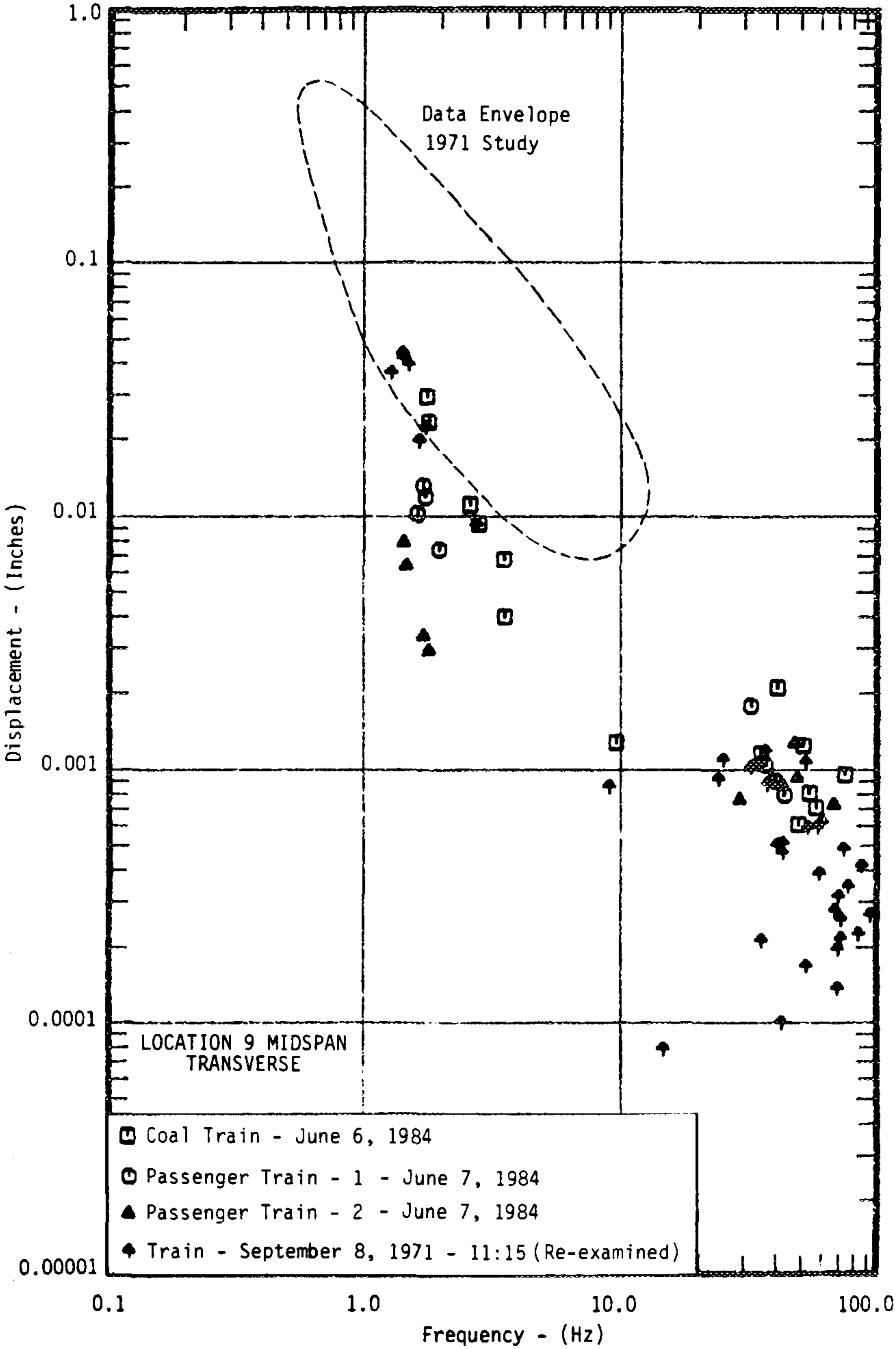


FIGURE A-2
Weston Geophysical

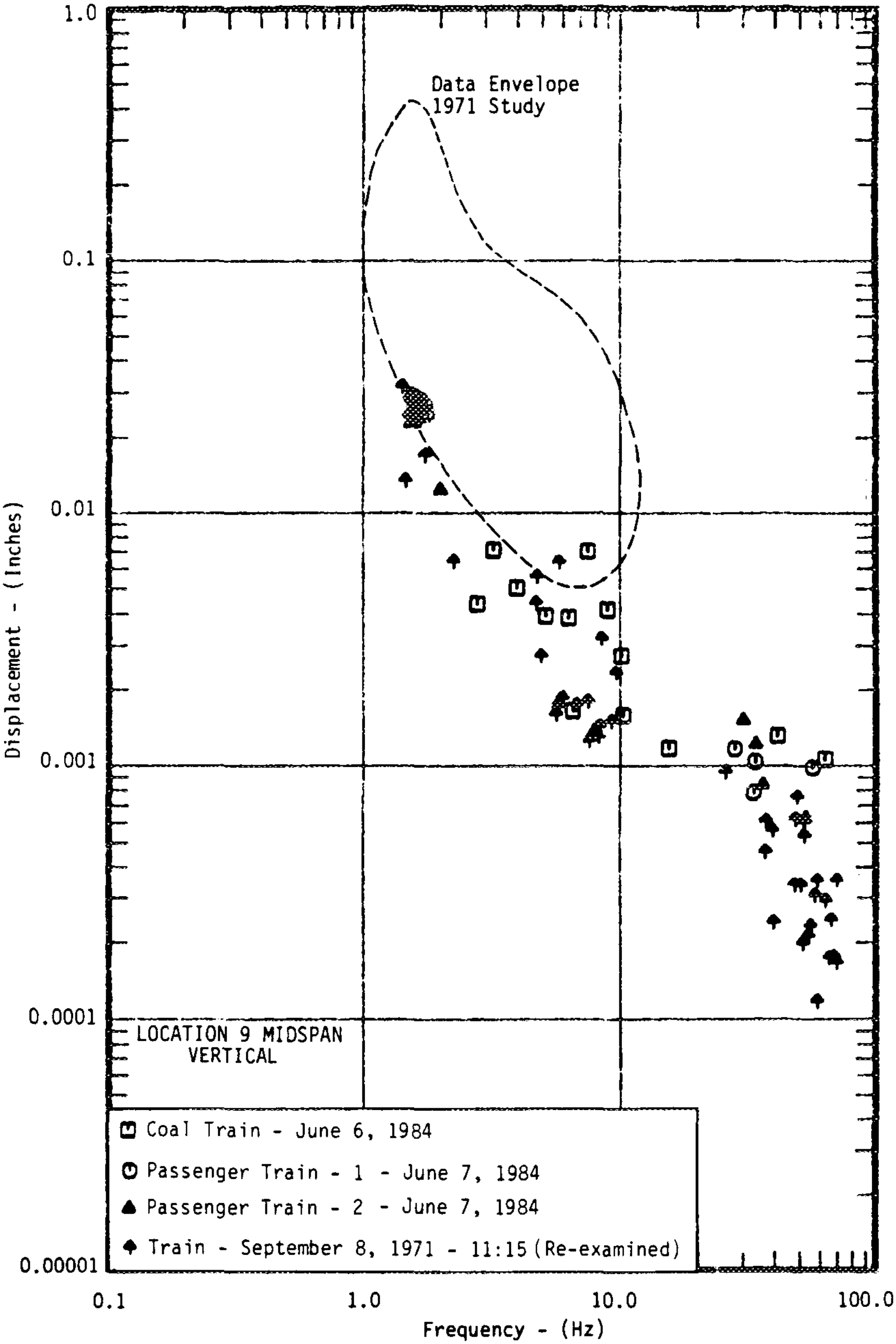


FIGURE A-3
Weston Geophysical

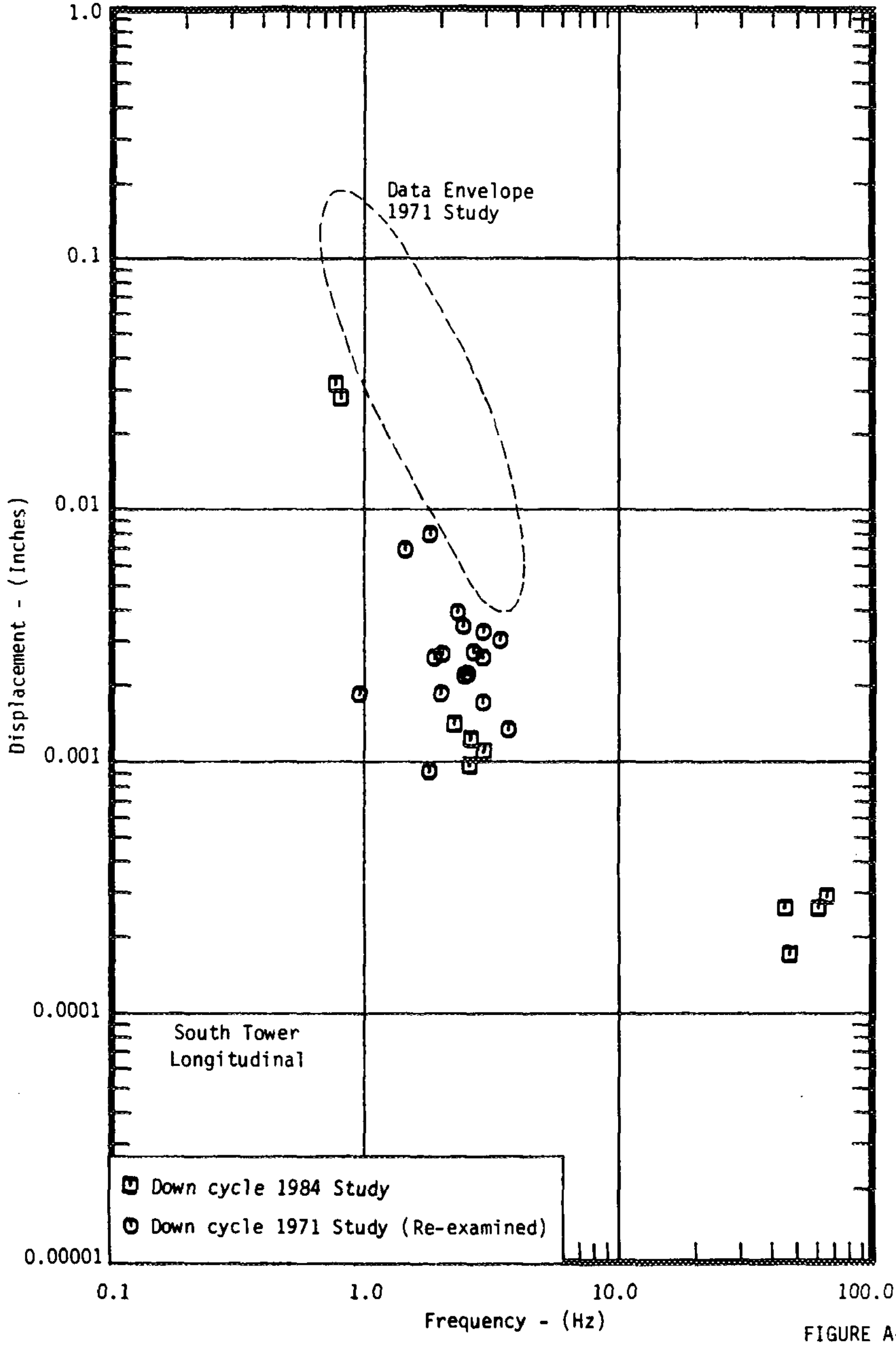


FIGURE A-4
Weston Geophysical

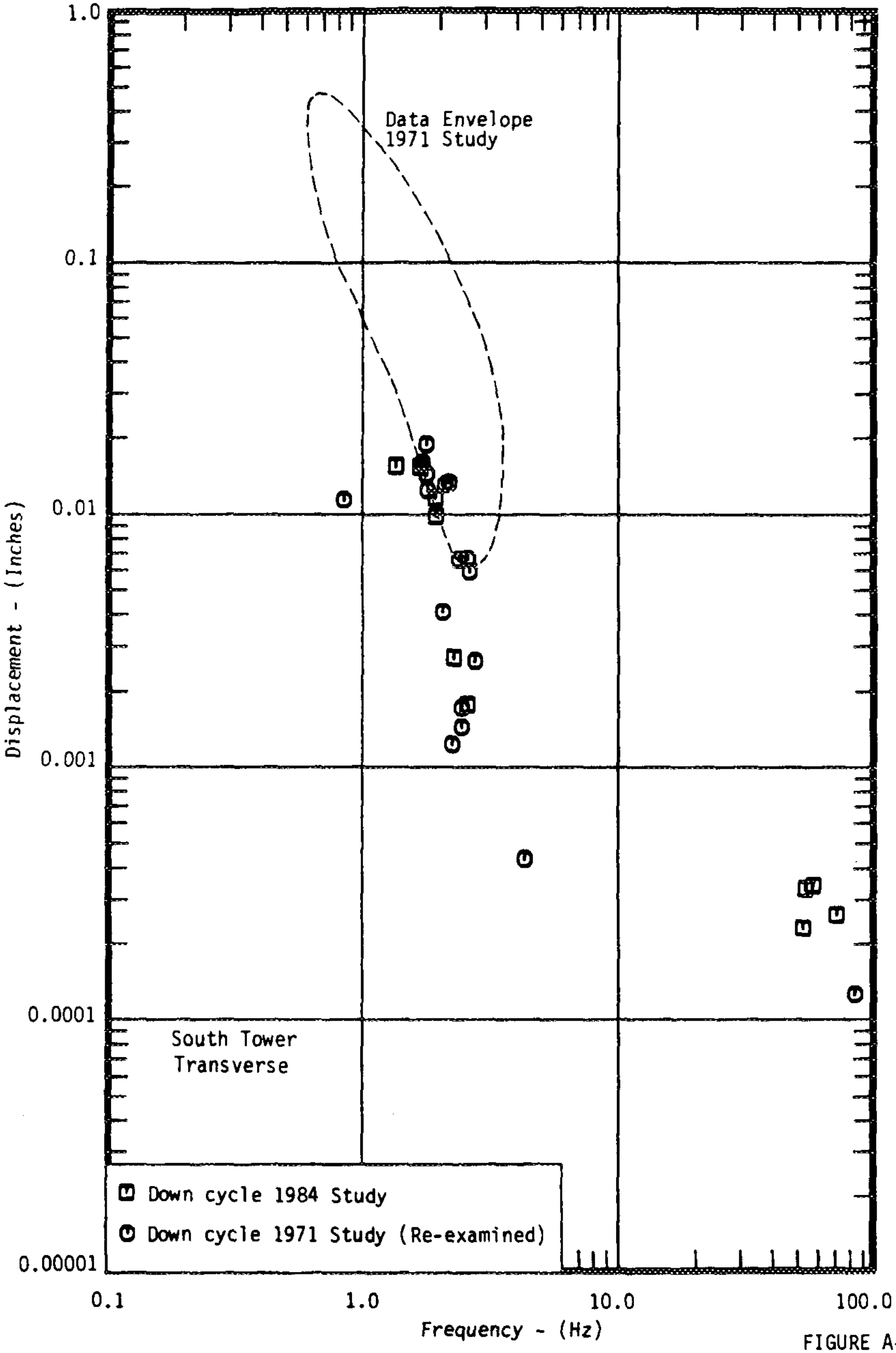


FIGURE A-5
Weston Geophysical

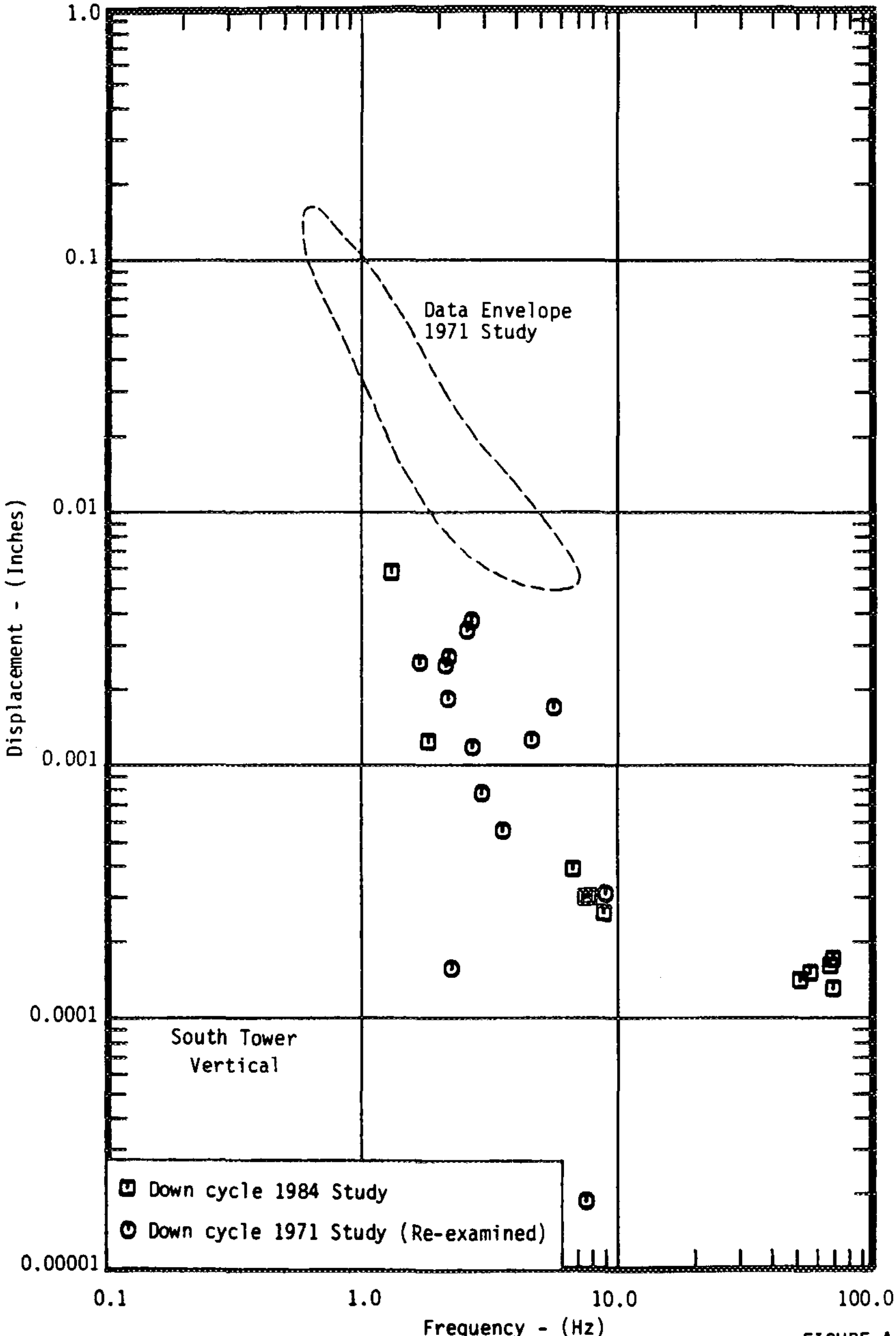


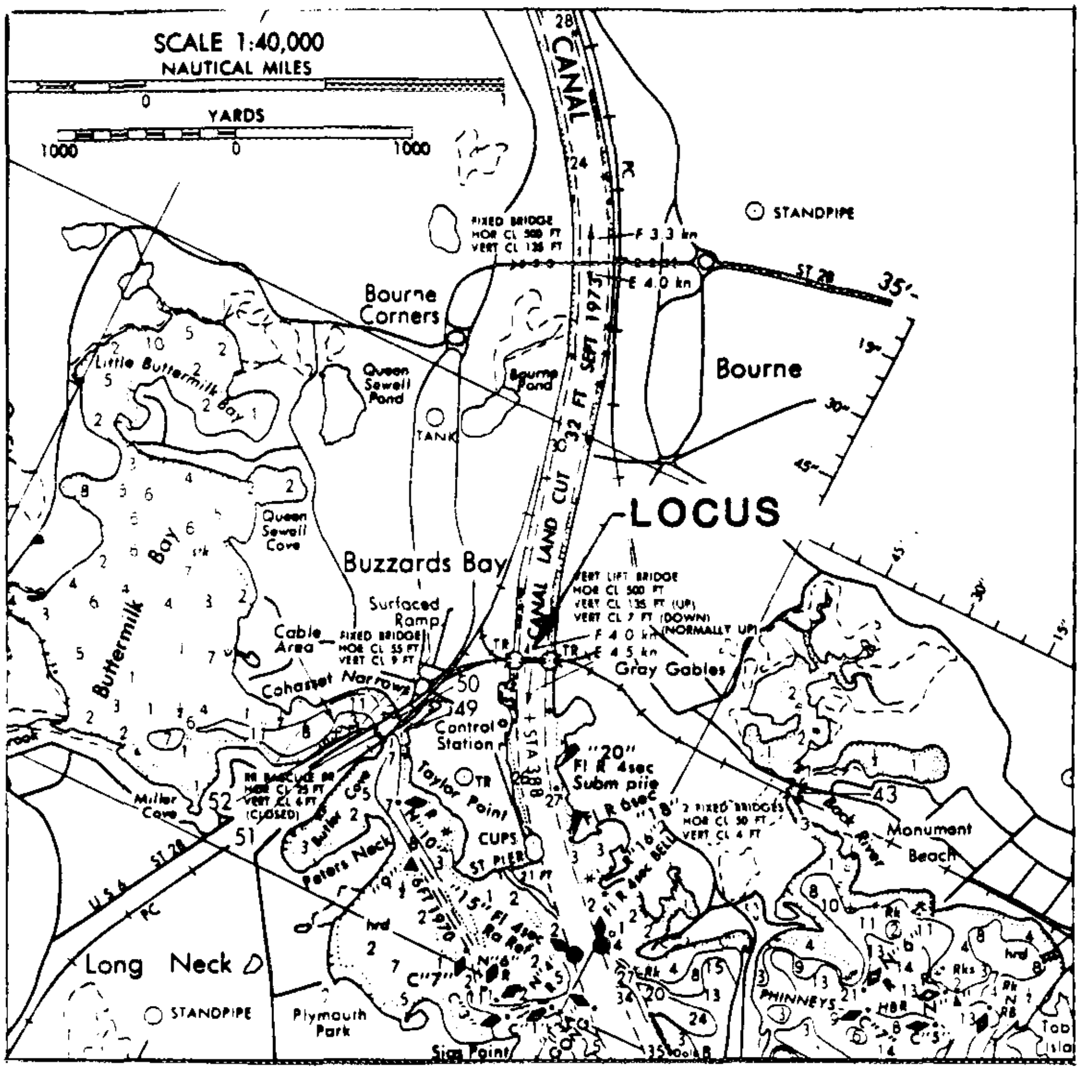
FIGURE A-6
Weston Geophysical

APPENDIX E

UNDERWATER INSPECTION REPORT

INSPECTION OF BRIDGE PIERS
VERTICAL LIFT RAILROAD BRIDGE
CAPE COD CANAL, BUZZARDS BAY, MA

MAY 1984



PREPARED BY: CHILDS ENGINEERING CORPORATION
MEDFIELD, MA

FOR: MODJESKI AND MASTERS
HARRISBURG, PA

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1.0 INTRODUCTION

The following Condition Survey Report was prepared by Childs Engineering Corporation under an agreement with Modjeski & Masters. As required by this agreement, Childs Engineering Corporation performed a structural condition survey of two (2) bridge piers supporting the main towers of the Cape Cod Canal vertical lift railroad bridge (see Figure 597-84-1 and Photo #1). This report presents the results of the Condition Survey and recommendations for the repair of any damaged or deteriorated portions noted in the survey.

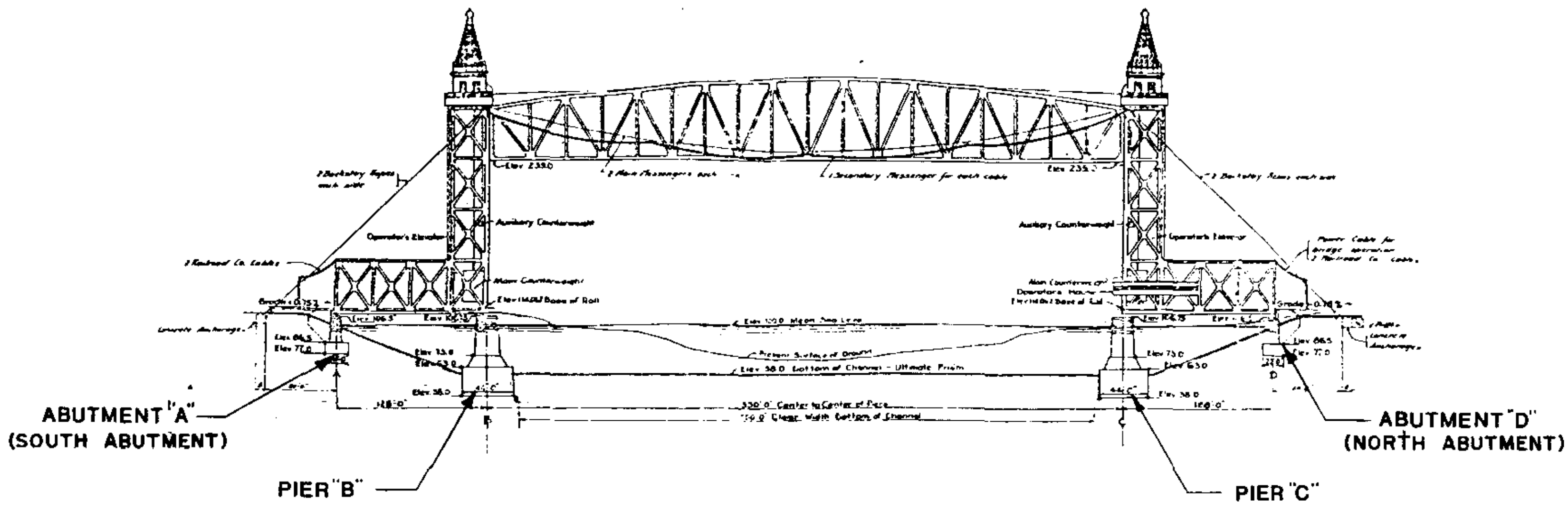
1.1 REPORT CONTENT

To provide a clear understanding of the work accomplished, the content of this report will be divided into three parts:

Section 2.0 Inspection Procedure - explaining diving procedures and inspection methods.

Section 3.0 Existing Conditions - a presentation of data along with drawings and photographic documentation of typical and atypical conditions.

Section 4.0 Structural Assessment and Recommendations - assessment of noted deterioration relating to the structure and recommendations for the repair of noted deterioration and an estimate of repair costs based on present day values.



ELEVATION

NO SCALE

NOTE: AS BUILT CONDITIONS ARE ILLUSTRATED
ON FIGURES 2 THRU 5

VERTICAL LIFT RAILROAD BRIDGE

CAPE COD CANAL, BUZZARDS BAY, MA

REFERENCED FROM SHEET 4A OF CONTRACT DWGS. MARCH 21, 1935

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FIG 597-84-1

2.0 INSPECTION PROCEDURE

Above and below water inspection of Piers B and C were performed by engineer/divers from Childs Engineering Corporation. The abovewater inspection was limited to visual, non-destructive techniques including confirming existing dimensions, general observations and photographic documentation of anomalies and typical conditions.

The below water inspection was performed using a surface-supplied air system (see Photos #2, #3, #4, #5). At all times the diver was tethered to the pier. Hard wire communications between the engineer/diver and engineer/tender facilitated efficient, accurate notekeeping as well as an additional factor of safety. Due to severe tidal currents (4-5 knots) in the canal, all underwater inspection was performed during periods of slack water.

Of the various inspection techniques employed, all were non-destructive. Selected locations on the pier structures were cleaned of biofouling in order to closely examine the exposed surface. Testing the soundness of the concrete involved striking its surface with a hammer to gauge its density. Thickness measurements of the steel sheet pile surrounding the concrete base were taken at selected elevations using a Krautkramer D-meter equipped with an underwater probe.

During the investigation no earth removal work or structural demolition was performed. The conditions noted reflect direct observation or measurement of structural components which were accessible. Evaluations of the conditions of hidden components are based on our engineering experience or generally accepted engineering theories.

3.0 EXISTING CONDITIONS

The description of the existing conditions encountered shall deal with the two piers, B and C, individually. Figures and photographs shall be included chronologically within each description.

3.1 GENERAL OBSERVATIONS

Stones ranging in size from 12" to 18" have been placed on top of both concrete bases adjacent to the pier stem structure at El. 75.0.

The full perimeter of the concrete bases could not be inspected due to the elevation of the mudline between the concrete base and its adjacent abutment. The mudline rises above the elevation of the top of the steel sheet pile, therefore blocking access to the sheet pile.

The condition of the inaccessible portions of the structure, i.e., timber piles, interior concrete and the steel sheet pile below the mudline, can be assumed to be of comparable condition to the accessable portions of the structure.

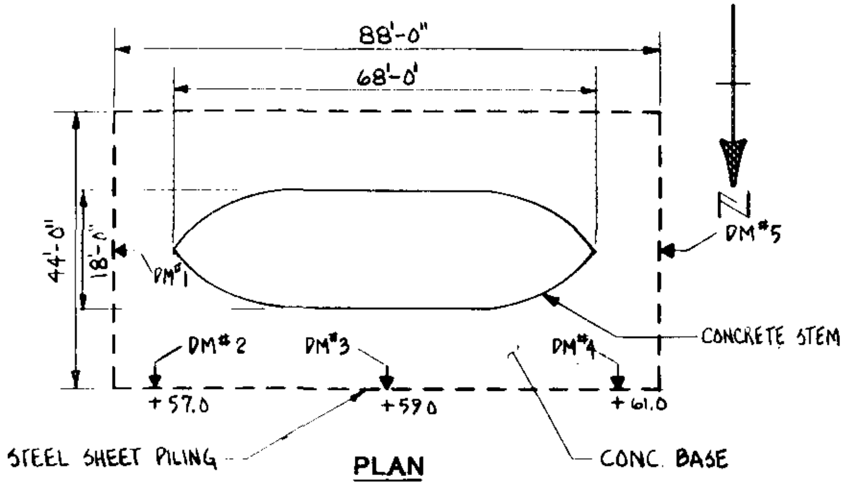
There is no existing fender system about the perimeter of either pier. Minor hairline cracking is noted on the concrete coping of both piers (see Modjeski and Masters report). The submarine cable ducts on both piers were observed to be in excellent condition.

3.2 PIER B

Heavy marine growth covered all portions of Pier B from elevation 100.0 to the mudline [ML] (see Photo #6). This growth consists mainly of mussels and sponges along with thin layers of algae. In some locations the mussel growth is up to 1 foot thick. From Elevation 100.0 to approximately Elevation 103.0 there is light barnacle growth on the granite block face.

The underwater concrete portions of the pier appeared to be in sound condition. There was no spalling, cracking or deterioration of the concrete noted. When struck with a hammer, the concrete was found to have 1/8" or less layer of softness. The abovewater concrete portion of the structure (concrete coping) was observed to be deteriorating (see Photos #7 and #8). Spalling to a depth of approximately 1/2" - 3/4" accompanied by hairline cracking is present on the concrete surface at the northwest end of the pier. For additional detailed condition of coping see Modjeski and Masters report.

The steel sheet piles are generally in good condition. Ultrasonic steel thickness readings indicate a minimum steel thickness of .215" (flange), however, average readings were considerably higher (.330" web; .400" flange), see Figure 597-84-2 for thickness readings, locations and elevations. The cleaned surface of the steel is slightly pitted with a maximum depth of less than 1/16" (see Photo #9). Corrosion by-product which covers the steel is 3/8" to 1/2" thick with an outer layer of hard, crusty material. Below the outer



PLAN

(OF D-METER STATIONS)

LEGEND

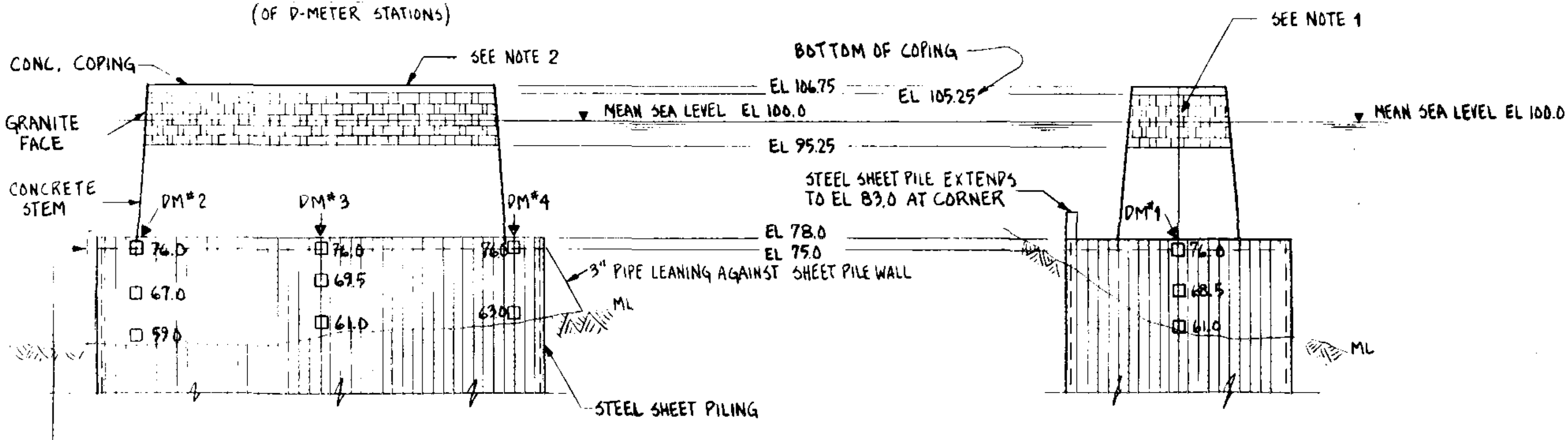
DM#3	LOCATION OF D-METER STATION
□ 67.5	D-METER READING ELEVATION
+ 75.0	SOUNDING IN FEET WITH REFERENCE TO MSL AS EL 100.0
--	STEEL THICKNESS READING NOT AVAILABLE

NOTES

1. APROX 42 LINEAR FEET OF DETERIORATED JOINT GROUT IS NOTED @ THE EAST END OF PIER B @ EL 103.25 AND EL 101.25 TO A MAX. DEPTH OF 6"
2. HAIRLINE CRACKING IS NOTED ON FACE OF COPING AND IS ASSOCIATED WITH SPALLING ON THE DECK
3. CONCRETE STEM DIMENSIONS TAKEN @ EL 105.25

STEEL THICKNESS READINGS

Station	El.	Reading Web.	Flange
DM#1	76.0	.330"	.460"
	68.5	.360	.510
	61	.330	.410
DM#2	76	.315	.325
	67	.365	.475
	51	.335	.390
DM#3	76	.280	.370
	69.5	.315	.455
	61	.325	--
DM#4	76	.265	.215
	63	.345	--
DM#5	68	.335	--



NORTH ELEVATION

EAST ELEVATION

...ATION OF IMPACT DAMAGE TO SHEET PILES SEE FIG 597-84-3 FOR DETAIL

PIER B

GRAPHIC SCALE 0 5' 10' 15' 20' 30' 40'

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FIG 597-84-2

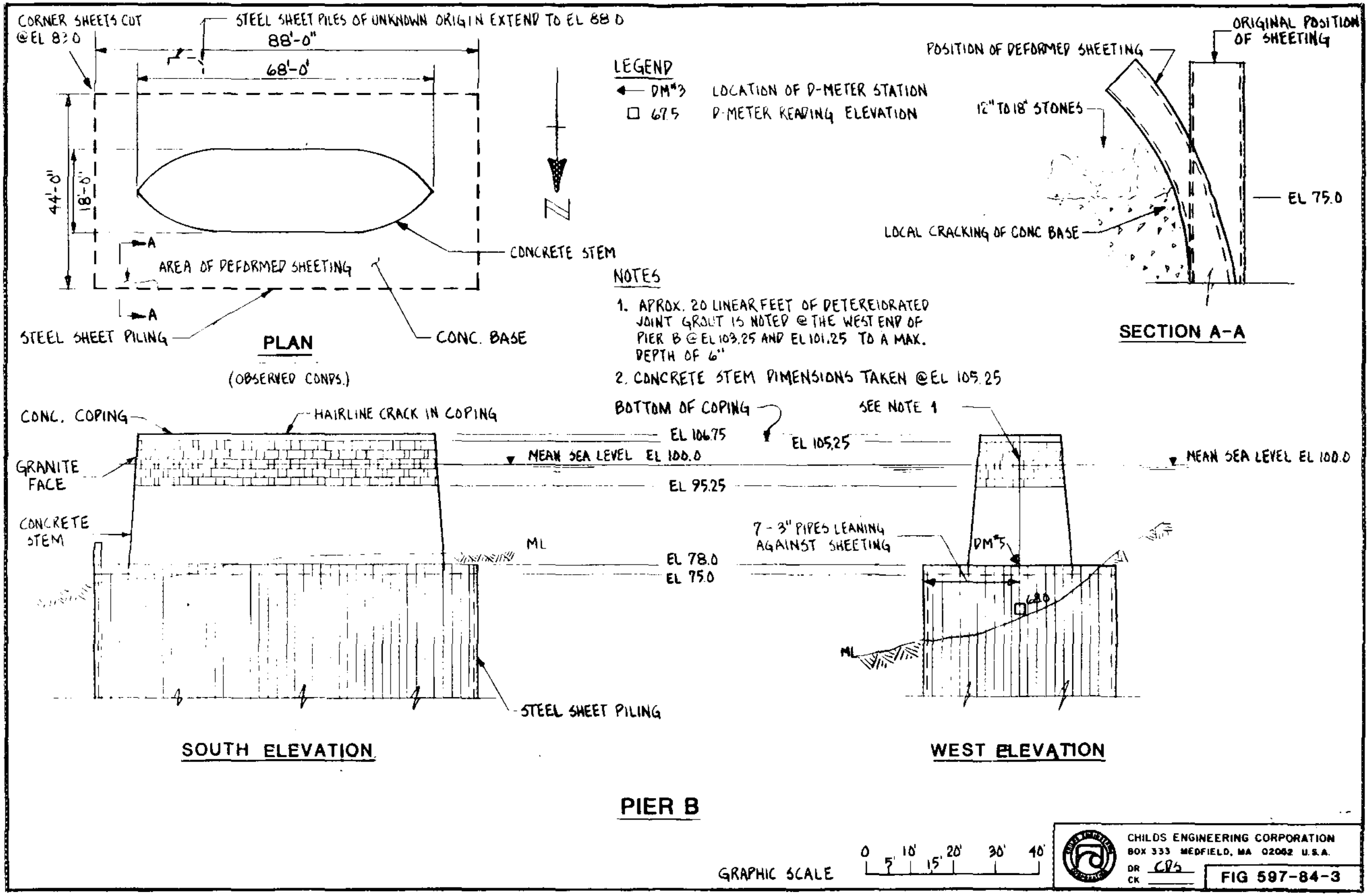
CORNER SHEETS CUT @EL 83.0
STEEL SHEET PILES OF UNKNOWN ORIGIN EXTEND TO EL 88.0
88'-0"
68'-0"
44'-0"
18'-0"
A
AREA OF DEFORMED SHEETING
CONCRETE STEM
STEEL SHEET PILING
CONC. BASE
PLAN
(OBSERVED CONDS.)
N
LEGEND
DM#3 LOCATION OF D-METER STATION
67.5 D-METER READING ELEVATION
NOTES
1. APROX. 20 LINEAR FEET OF DETEREIORATED JOINT GROUT IS NOTED @ THE WEST END OF PIER B @ EL 103.25 AND EL 101.25 TO A MAX. DEPTH OF 6"
2. CONCRETE STEM DIMENSIONS TAKEN @EL 105.25
POSITION OF DEFORMED SHEETING
ORIGINAL POSITION OF SHEETING
12" TO 18" STONES
EL 75.0
LOCAL CRACKING OF CONC BASE
SECTION A-A
CONC. COPING
HAIRLINE CRACK IN COPING
GRANITE FACE
CONCRETE STEM
BOTTOM OF COPING
SEE NOTE 1
EL 106.75
EL 105.25
MEAN SEA LEVEL EL 100.0
EL 95.25
ML
EL 78.0
EL 75.0
7 - 3" PIPES LEANING AGAINST SHEETING
DM#5
68.0
STEEL SHEET PILING
SOUTH ELEVATION
WEST ELEVATION
PIER B
GRAPHIC SCALE
0 5' 10' 15' 20' 30' 40'
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FIG 597-84-3

layer there are trapped gas pockets accompanying a soft black layer of corrosion by-product.

Along the northeast corner of the concrete base there is an 8-foot section of the steel sheet pile wall which has been damaged. The damage begins at the northeast corner and runs to the west at the top of the sheet pile (El. 75.0 to El. 65.0). In this area the steel sheeting has been flattened and folded over the concrete edge (El. 75.0) to the southerly direction (see Photo #10). Due to the deflection and deformation, there is one hole (1"x5") in the flange of the fifth sheet as counted from the corner to the west at El.74.0 (see Figure 597-84-3). There is some local crushing of the concrete in this area, however, this damage appears to be minor.

At the southeast corner of the concrete base the steel sheeting has not been cut to grade (El. 77.0). The top of the corner sheets were left at El. 83.0. Also three sections of sheeting were found 10 feet to the south of the concrete base and approximately 25 feet to the west of the southeast corner of the concrete base. The tops of these sections of sheeting were left at El. 88.0.

At the west face of the concrete base there are seven 3" pipes leaning against the steel sheet pile wall (see Photo #11). They are spaced at approximately 2' on center from the east-west center line of the pier to the northwest corner. Apparently the pipes have no function at the present time.

Joints between granite blocks are generally found to be in excellent condition (see Photos #12, #13, #14, #15). At the east and west ends there are some joints with grout deteriorated at El. 103.25 and El.101.25 (second and third joints below concrete coping) to a maximum depth of 10". Pier B has a total of 62 linear feet of deteriorated joint grout.

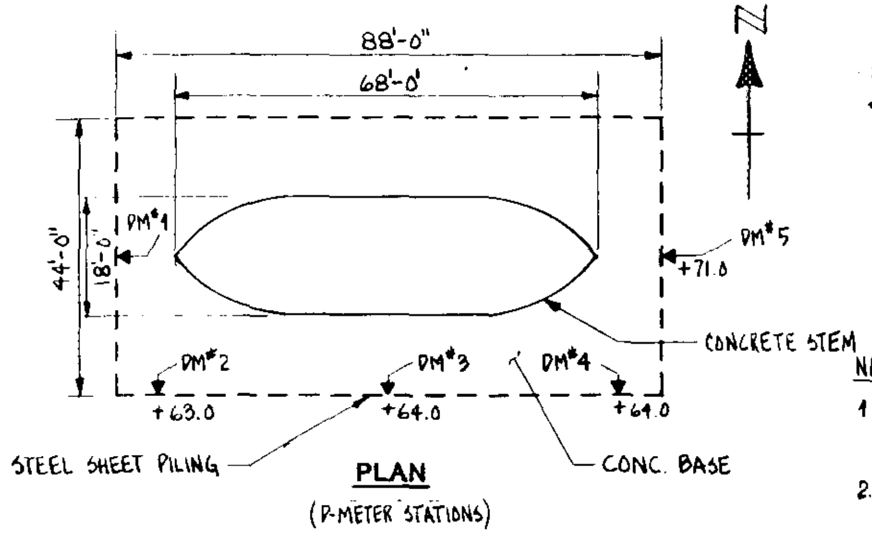
3.3 PIER C

The marine growth profile for Pier C is similar to that of Pier B. Underwater portions of the structure are covered with a heavy layer of marine growth largely consisting of mussels up to 1' thick.

Submerged portions of the exposed concrete were found to be in excellent condition. When struck with a hammer, the concrete was found to have less than 1/8" of softness (see Photo #16). The abovewater concrete (concrete coping) exhibits some light spalling (less than 1/2" deep) and hairline cracking. See Modjeski and Masters report for further coping details.

The steel sheet piles are in good condition. After cleaning the surface of the steel, slight pitting was observed on the steel surface with the pits being less than 1/16" deep (see Photo #17). A corrosion profile of the steel is similar to Pier B with an outer layer of hard, crusty material. Behind the outer layer are trapped pockets of gas and a soft black layer of corrosion by-product (see Photo #18). Ultrasonic steel thickness readings indicate a minimal steel thickness of .205" (flange); however, average readings were considerably higher (.390, flange; .315, web) see Figure 597-84-4 for thickness readings, locations and elevations.

There is one split interlock along the channel face approximately 20' to the west of the southeast corner. The split originates approximately 4' above the ML. At the ML the sheet separation is approximately 3". Concrete, which is exposed at the separation, appears to be in sound condition.



PLAN

(D-METER STATIONS)

LEGEND

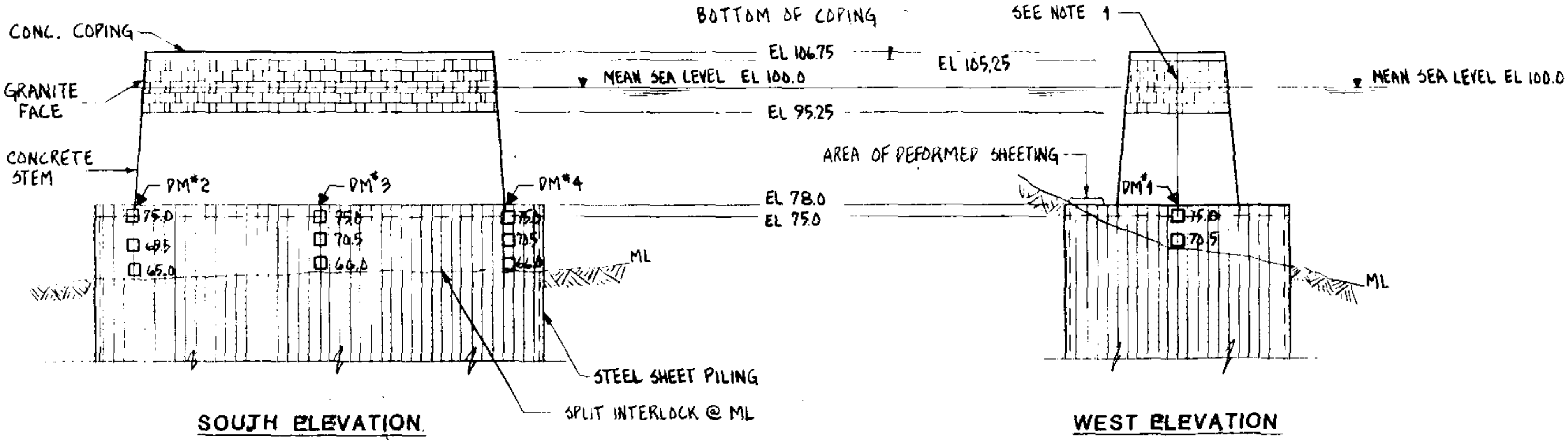
- DM#3 — LOCATION OF D-METER STATION
- □ 67.5 — D-METER READING ELEVATION
- + 75.0 — SOUNDING IN FEET WITH REFERENCE TO MSL AS EL 100.0

STEEL THICKNESS READINGS

Station	El.	Reading Web	Reading Flange
DM#1	75	.335"	.425"
	70.5	.425	.320
DM#2	75	.330	.205
	69.5	.315	.415
	65	.315	.440
DM#3	75	.300	.395
	70.5	.305	.435
	66.0	.335	.405
DM#4	75	.300	.310
	70.5	.305	.435
	66	.330	.425
DM#5	76	.305	.415
	73	.310	.485

NOTES

1. APROX. 20LF OF DETERIORATED JOINT GROUT IS NOTED @ THE WEST END OF PIER C AT EL 103.25 AND 101.25 TO A MAX. DEPTH OF 6"
2. CONCRETE STEM DIMENSIONS TAKEN @ EL 105.25



SOUTH ELEVATION

WEST ELEVATION

PIER C

GRAPHIC SCALE 0 5' 10' 15' 20' 30' 40'

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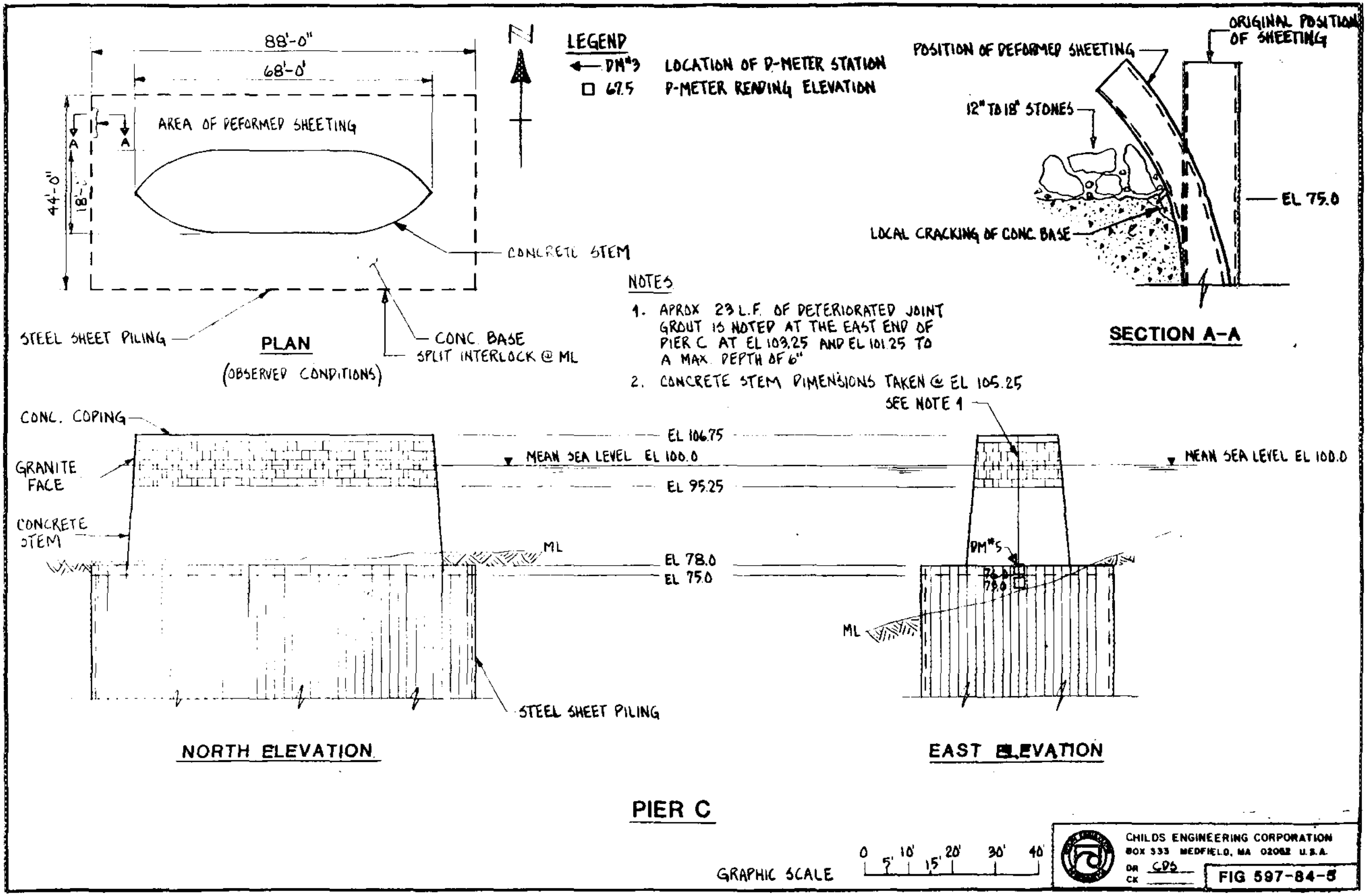
FIG 597-84-4



88'-0"
68'-0'
44'-0"
18'-0"
A
A
AREA OF DEFORMED SHEETING
CONCRETE STEM
STEEL SHEET PILING
CONC. BASE
SPLIT INTERLOCK @ ML
PLAN
(OBSERVED CONDITIONS)
N
LEGEND
DM#3 LOCATION OF D-METER STATION
67.5 D-METER READING ELEVATION
NOTES
1. APROX 23 L.F. OF DETERIORATED JOINT GROUT IS NOTED AT THE EAST END OF PIER C AT EL 103.25 AND EL 101.25 TO A MAX. DEPTH OF 6"
2. CONCRETE STEM DIMENSIONS TAKEN @ EL 105.25
ORIGINAL POSITION OF SHEETING
POSITION OF DEFORMED SHEETING
12" TO 18" STONES
EL 75.0
LOCAL CRACKING OF CONC. BASE
SECTION A-A
CONC. COPING
GRANITE FACE
CONCRETE STEM
ML
EL 106.75
MEAN SEA LEVEL EL 100.0
EL 95.25
EL 78.0
EL 75.0
STEEL SHEET PILING
NORTH ELEVATION
SEE NOTE 1
MEAN SEA LEVEL EL 100.0
DM#5
76.0
75.0
ML
EAST ELEVATION
PIER C
GRAPHIC SCALE
0 5' 10' 15' 20' 30' 40'
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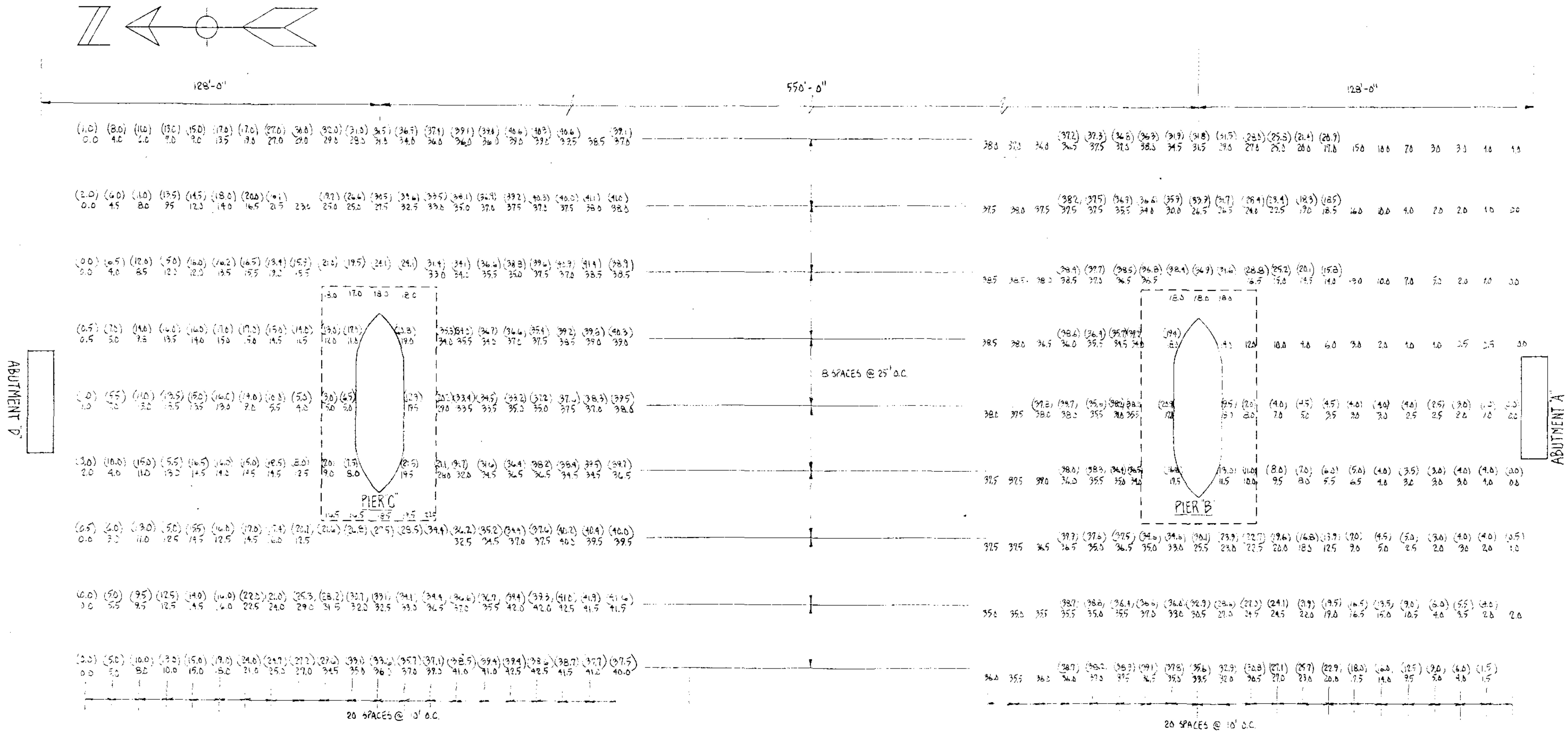
FIG 597-84-5

At the northwest corner of the concrete base the exposed sheet piles have been folded over the top of the concrete edge (El. 75.0) to the easterly direction (see Figure 597-84-5). The full extent of this damage could not be determined due to the elevation of the mudline (El. 74.0) in that area. The damage appears to be minor with no structural significance.

Joints between granite blocks are generally found to be in excellent condition. At the east and west ends there are some joints with grout deteriorated at El. 103.25 and El. 101.25 (second and third joints below concrete coping) to a maximum depth of 10" (see Photos #19 and #20). Pier C has a total of 50 linear feet of deteriorated joint grout.

3.3 SOUNDINGS

Fathometer runs were made about the pier foundations of the railroad lift bridge (see Figure 597-84-6) with a white line recorder. Established elevations were used to gauge the water level at the time of each run. Adjustments were then made with the data being referenced to mean low water.



NOTES

1. SOUNDINGS ARE IN FEET BELOW M.L.W.

LEGEND

(25.3) SOUNDING TAKEN AUGUST 1971

34.0 SOUNDING TAKEN MAY 1984

SOUNDINGS

TAKEN ABOUT PIERS "B" AND "C" OF THE VERTICAL LIFT RAILROAD BRIDGE

CAPE COD CANAL, BUZZARDS BAY, MA

SCALE 1" = 20'

REVISION

Childs Engineering Corporation

Box 333 Medfield, Mass. 02052 U.S.A.

Drawn CPS

Checked

Approved

FIG-597-84-6

4.0 STRUCTURAL ASSESSMENT AND RECOMMENDATIONS

Both Piers B and C are in excellent condition; however, there are a few minor anomalies which left unattended could become marginal conditions.

Apparently the steel sheet piling surrounding the piers is not functioning as a structural element. Originally it was placed as a cofferdam and used later as a concrete form. Presently it is providing protection to the interior concrete. The loss of steel due to corrosion is not significant structurally at this time; however, the steel is providing an effective protective barrier to the concrete.

The two locations where an apparent impact has occurred to the concrete base, (Pier B, northeast corner; Pier C, northwest corner), exhibit only local damage to the structure. However, it should be determined through established survey points that the impact did not shift the structure's foundation.

A split interlock was noted on Pier C along the channel face. This condition is stable and does not appear to be structurally significant at this time.

The function of the three sections of sheeting which were found to the south of the concrete base of Pier B could not be determined. However, it appears that they are not an integral portion of the tower foundation and were probably a temporary structure for the construction of the concrete base. To the south of Pier B the three portions of the sheet pile wall which have not been cut to grade should be burned off at the proper elevation if they pose a navigational hazard to small craft operating to the south of Pier B. The estimated cost to burn the sheets off at grade (El. 77.0 or ML) would be approximately $2,000.

The deterioration of joint grout between granite blocks is apparently caused by ice erosion and/or abrasion and is generally more prevalent at the pier heads. All areas of deteriorated grout should be removed back to sound grout and then replaced with new grout. The estimated cost per linear foot is $3.00. The total estimated cost for Piers B and C is $336.00 plus mobilization and demobilization.

The above and below water repairs to be made should be inspected immediately following implementation for quality control. The underwater portions of the structure should be inspected on a 6-year basis to determine any change of conditions. Following the implementation of the recommended repairs, the useful life of Piers B and C is estimated to be in excess of 25 years.

A comparison of soundings taken in 1971 and 1984 indicates that there has been little or no change in channel elevation since 1971.